WIRELESS ENGINEER

THE JOURNAL OF RADIO RESEARCH & PROGRESS

JUNE 1950

VOL. XXVII TWO SHILLINGS AND SIXPENCE No. 321

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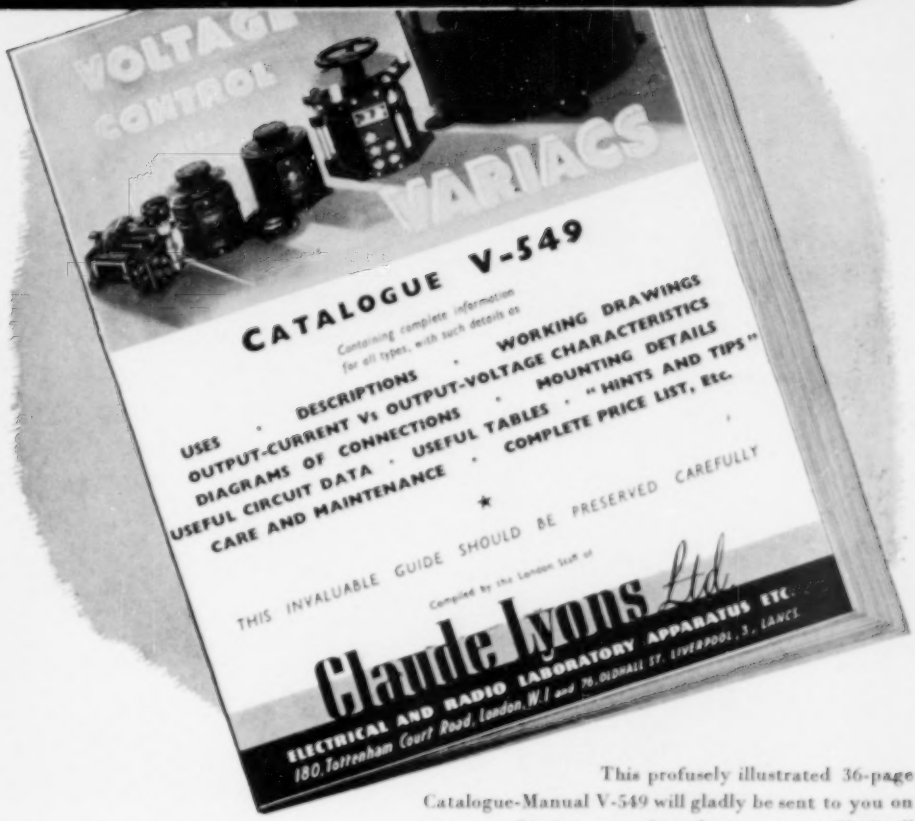
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VARIACS
CATALOGUE V-549
Containing complete information for all types, with such details as
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OUTPUT-CURRENT V1 OUTPUT-VOLTAGE CHARACTERISTICS
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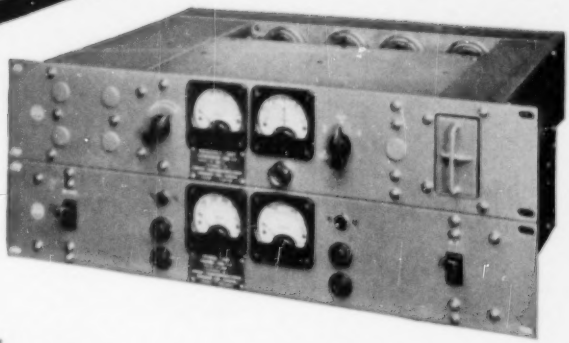

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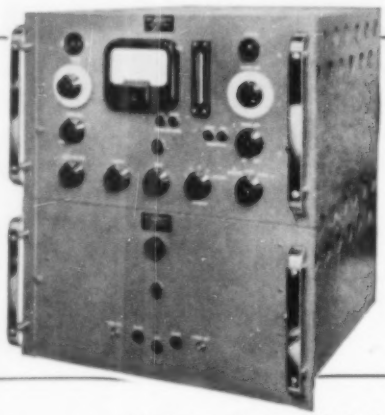

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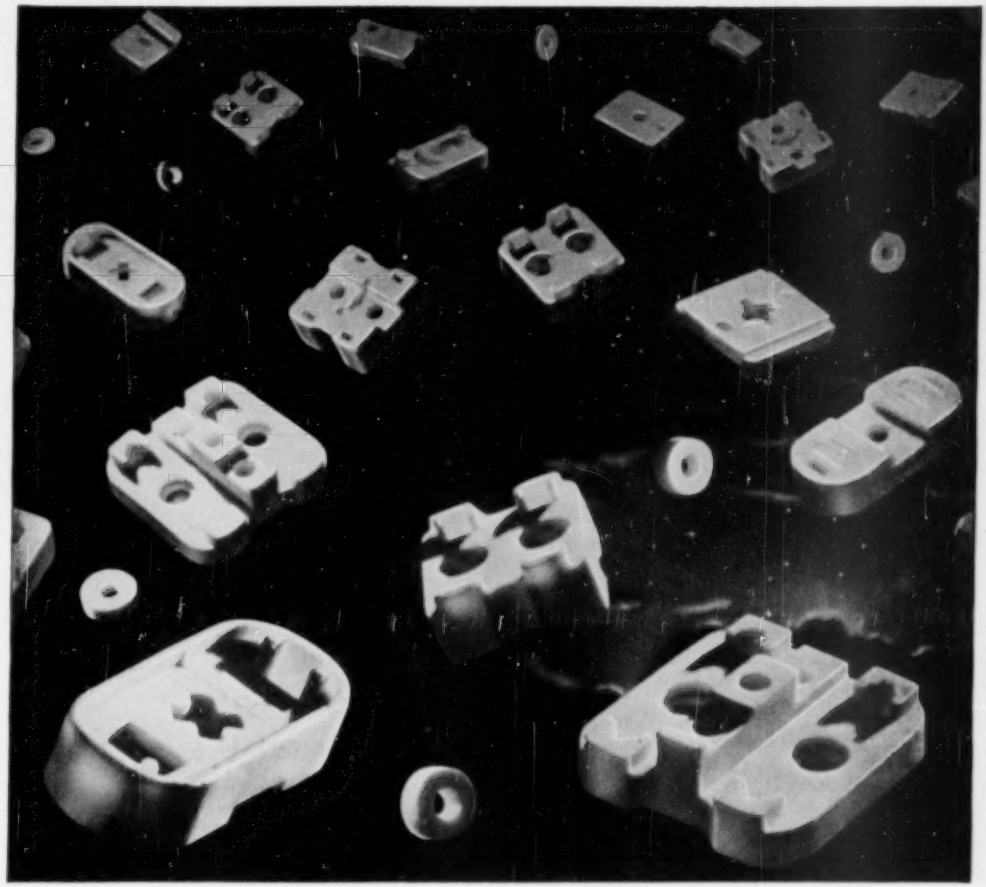

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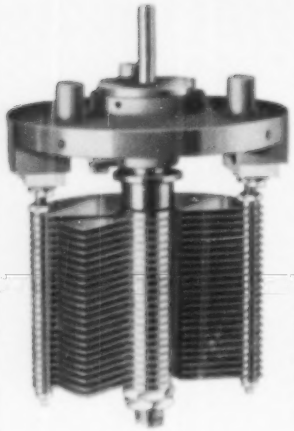

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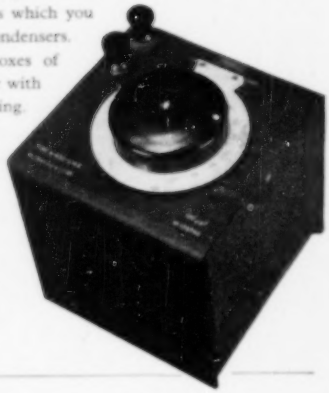

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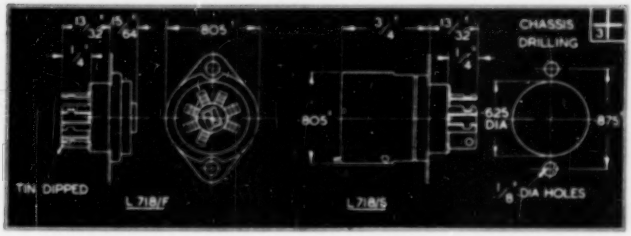

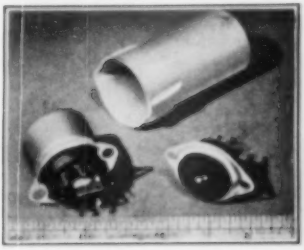

At the time of going to press the "Belling-Lee" versions of these valveholders have reached their final tool making stage and we hope small production will commence within a few weeks and full production in two to three months.

It is intended to supply the holders with either fixing flanges or skirts to take the standard screening cans.

We anticipate that these types will meet the requirements of the services, of the electronic instrument manufacturer and perhaps a few of the manufacturers of the more expensive domestic receivers. They are intended to fill the gap between the cheaper types and the very expensive P.T.F.E. holders but are likely to prove too expensive for cheaper commercial receivers. The insulators are moulded from high quality nylon filled powder and a new flat type screen is incorporated giving the desired screening between contacts, and this can be cut down if necessary for application where space is limited.

The contacts are made of silver plated beryllium copper differentially hardened to obtain the best possible contact pressure. The solder tags remain annealed and are tin dipped for ease of soldering.

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L720/F with Flange
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(Inter service reference numbers pending)

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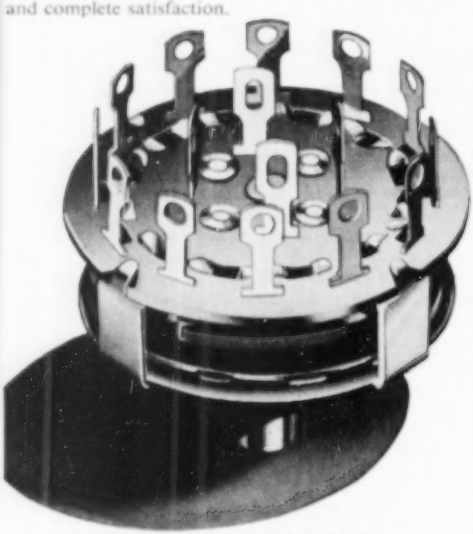

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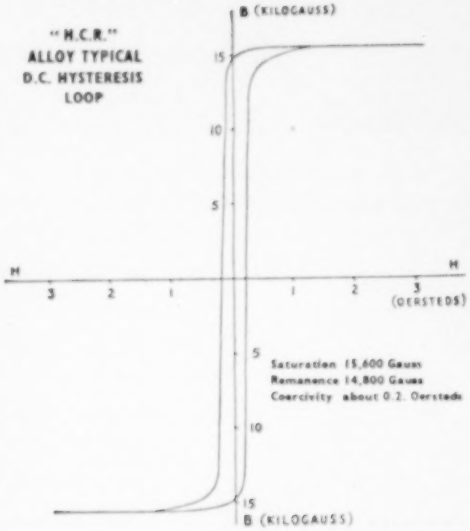

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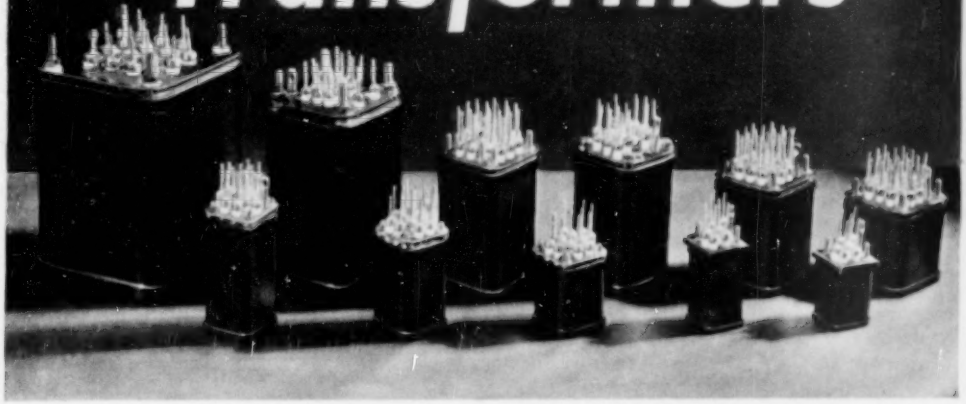
Transformers



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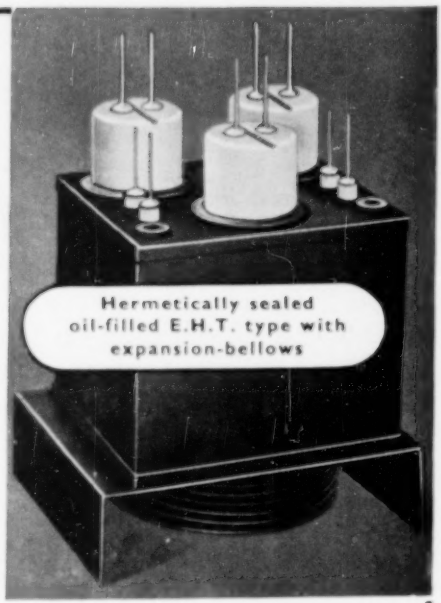

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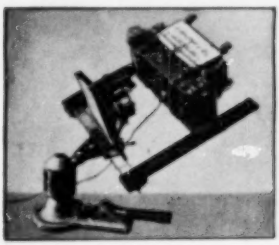

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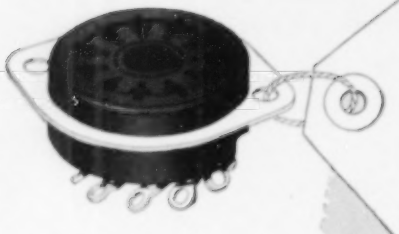

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Ref. No. **S.P.11U** moulded in **Phenol-Formaldehyde with moulded-in metal mounting plate**
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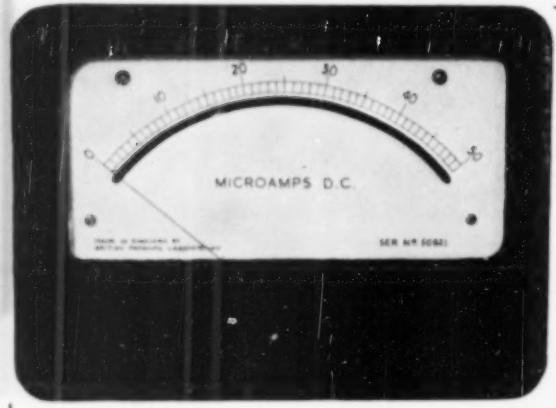

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PRICE			
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Approx. Fil. Current (amps)	0.8
Maximum Anode Current (mA)	3.0
Maximum Anode Voltage (volts)	100

DIMENSIONS:

Maximum Overall Length (mm)	80
Maximum Diameter (mm)	32
Maximum Seated Height (mm)	67

TYPICAL OPERATION

Saturated Anode Current (mA)	2.0
Minimum Anode Voltage (volts)	20.0
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†Taken at $V_a = V_{g2} = 150$ volts; $I_a = 200$ mA

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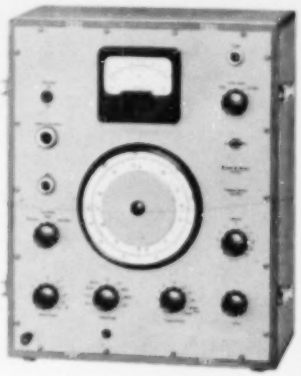

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Scales: From 0 to 100 microvolts and from 10 to + 20 db.
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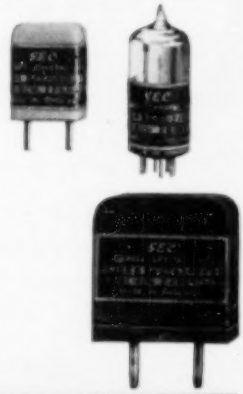

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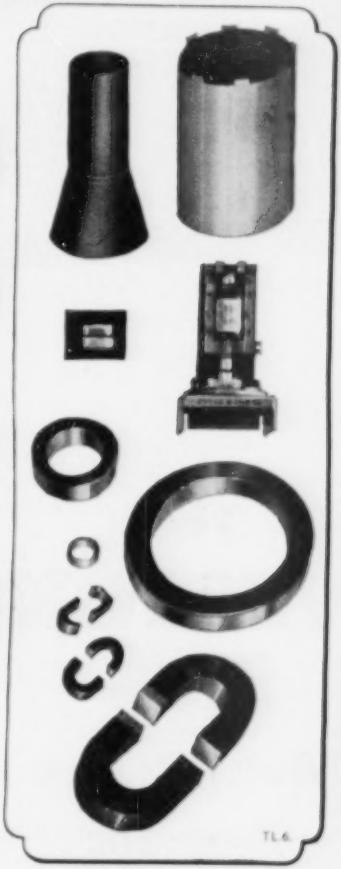

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JUNE 1950

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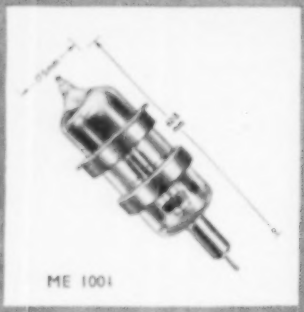

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	ME 1001	ME 1003
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Max. Anode Dissipation (W)	10	25
Max. Anode Current (mA)	50	200
Max. Peak Anode Current (mA)	150	500
Power Output (W)	0.8 (at 3000 Mc/s) 3.5 (at 800 Mc/s)	6 (at 1500 Mc/s) 20 (at 430 Mc/s)
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MVT 64

WIRELESS ENGINEER

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A Problem of Electromagnetic Induction

IN the Editorial of July 1939 we considered among other interesting problems that of the e.m.f. induced in a cylinder made up of alternate segments of brass and iron when rotated in an axial magnetic field. When this was briefly described in a recent lecture it raised some interesting discussion, which indicated that the problem is worth further consideration, especially when the spaces occupied by the brass and iron are not equal. Fig. 1 shows such a cylinder rotating in an axial field between two poles, the field being produced by six magnetizing coils. We have adopted this arrangement to remove any question as to whether the magnetic field may rotate. We assume that the rotating cylinder is much longer than shown, so that end effects may be neglected. Eddy currents in the poles could be made negligible by constructing the poles of laminated strip wound in a spiral.

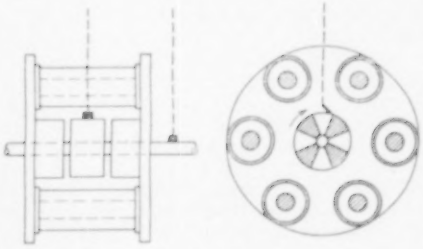


Fig. 1

A clear picture of what happens to the magnetic field can be obtained by the analogy shown in Fig. 2, which represents a race-track made up of alternate patches of land and water. A number of equally spaced runners are supposed to be running from right to left ; in the water, on account of their slow progress they are close together, but on emerging from the water their speed is greatly increased and their spacing increases.

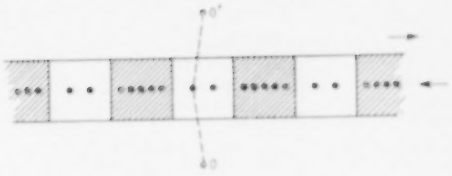


Fig. 2

The number of runners passing any point per minute is the same whether on land or in water, decrease of speed being counteracted by increase in density. If now we picture the whole track moving to the right at the average speed of a runner, to stationary observers such as OO' each runner will simply move to and fro and could be fastened to the observers by ' stretched elastic threads ' as shown by the dotted line. When in the water he will move slowly to the right, and when on dry land, rapidly to the left.

This is exactly what happens to the lines of magnetic induction as the cylinder rotates ; in the iron the density is much greater than in the brass and the lines move slowly in the direction of rotation, whereas in the brass they move rapidly backwards, but the number of lines cut per second is exactly the same whether the radius considered is in the iron or in the brass. The smaller flux density in the brass is counteracted by the higher speed with which the lines cut through the material. If the total magnetic flux along the cylinder is Φ and the speed n revolutions per second, then the induced e.m.f. in

any radius is $n\Phi$. On open circuit, assuming the direction of the magnetic flux in Fig. 1 to be away from us, the surface of the cylinder will be uniformly charged positively, the equivalent negative charge being uniformly distributed throughout the material of the cylinder.

We shall now assume that the cylinder is not made up of equal segments of brass and iron, but that a fraction α is of brass and the remainder $1-\alpha$ of iron of permeability μ. If R is the radius of the cylinder and B the flux density in the brass, then $\Phi = \pi R^2[\alpha B+(1-\alpha)\mu B]$ and for the induced e.m.f. we have $E = \pi R^2 n B[\alpha+(1-\alpha)\mu]$. If $\alpha = \frac{1}{4}$, the quantity in brackets is $(1+3\mu)/4$, if $\alpha = \frac{1}{2}$, it is $(1+\mu)/2$, and if $\alpha = \frac{3}{4}$, it is $(3+\mu)/4$.

If we approach the problem from the more abstract Maxwellian point of view, without the aid of race-track analogies, we find it much more difficult. In the brass the e.m.f. induced in 1 cm of radius *due to its movement* in the magnetic field is Bv, while in the iron it is μBv. To these we have to add the e.m.f. due to the change of flux through any stationary path; otherwise, although the mean value of Bv and μBv taken round the whole cylinder gives the correct value, the e.m.fs induced in the iron and brass are entirely different.

If in Fig. 3 the stationary path a b c d has a radial length of 1 cm, the e.m.f. induced around the path by the changing flux is $(\mu-1)Bv$, where v is the velocity with which the interface between the brass and iron is sweeping across the stationary path. We now come to the question that led to the writing of this article; how is this e.m.f. to be divided between a b and c d? Since there cannot be a discontinuity in the resultant radial electric force at the interface, the obvious answer is to divide the e.m.f. $(\mu-1)Bv$ into two parts such that the addition to the motional e.m.f. in the brass, and the subtraction from that in the iron give equal resultant e.m.fs. This is where the difficulty arises, for since $(\mu-1)Bv$ is exactly equal to the difference between the two motional e.m.fs, μBv and Bv, equal resultants are obtained however the circuital e.m.f. is divided between the two sides. If it is all added to Bv in the brass the resultant everywhere is μBv, whereas if it is all subtracted from μBv in the iron, the resultant everywhere is Bv. The correct division depends on something quite outside this application of Maxwell's laws; viz., the relative amounts of brass and iron in the cylinder; i.e., on the value of α. We have seen that the resultant in both brass and iron is $Bv[\alpha+(1-\alpha)\mu]$; hence the portion of the circuital e.m.f. in a b must be $Bv[\alpha+(1-\alpha)\mu]-Bv = Bv[(1-\alpha)(\mu-1)]$, while that in c d must be $\mu Bv - Bv[\alpha+(1-\alpha)\mu] = Bv[\alpha(\mu-1)]$. Hence we see that the circuital e.m.f. is divided between the brass and iron inversely as the proportion of these materials in the cylinder.

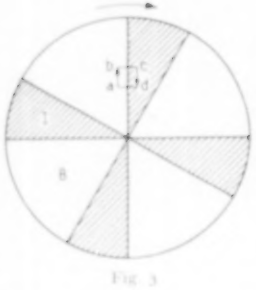


Fig. 3

Fig. 4

We feel that the application of the race-track analogy, and the treatment of the lines of magnetic induction as discrete physical entities throws more light on this problem than does the application of Maxwell's laws, which, in their simple form, appear to be incapable of giving a definite solution without the aid of the former. A mathematical correspondent remarked that he was not sure that theory gives a constant e.m.f. as the cylinder rotates, but that it is too complicated for rigorous calculation. This emphasizes the simplicity and the rigorous accuracy of the analogy, which can also be applied to the passage of the magnetic flux across the teeth and slots of a dynamo armature.

It is interesting to note that, if in Fig. 4 the narrow strips represent the cross-sections of iron cores in which the magnetic flux is changing at the same rate but in opposite directions in adjacent strips, the electric field induced in the surrounding medium will be approximately as shown. The values of the induced electric force $\mathscr{E}$ in the spaces between the cores are inversely proportional to the distances between the cores, and the circuital e.m.f. is divided between the two sides in the same way as in Fig. 3. G. W. O. H.

Readers will note a slight reduction in the number of pages in this issue of *Wireless Engineer*. This reduction has been necessitated by the withdrawal of overtime working by a section of the printing industry and has, in the circumstances, been unavoidable. We hope that it will be only temporary.

A USEFUL NETWORK PROCEDURE

By Sidney C. Dunn, M.Sc., A.M.I.E.E.

(Paisley Technical College)

THE method proposed establishes a relation between the parallel connection of quadripoles and the star connection of the same quadripoles. While the general network is considered first, the method is most useful in a particular case of frequent occurrence.

Consider the parallel connection of two T-networks as in Fig. 1 (a) working between generator and load each of finite impedance. The transfer response is given by

$$\frac{v}{e} = \frac{Z_s B_{14}}{D} \qquad \ldots\ldots\ldots\ldots \quad (1)$$

where D is the fourth-order determinant of the network (see Appendix) and B_{14} the cofactor formed by striking out row 1 and column 4 in D and multiplying the minor so formed by -1. The network has been redrawn in Fig 1 (b) to disclose the meshes involved.

Now replace the circuit by that of Fig. 2 which is formed by cutting through the network at the dotted line in Fig. 1 (a) and unfolding it so that the load resistor lies in the middle and the circuit is fed at each end by a zero-impedance generator of e.m.f. Ae. We will now find the value A must have in order that the response of this network will be the same as that of the previous one. It will be noted that we have reduced the number of effective meshes in the network from four to one since the circuit may be further rearranged as in Figs. 3 (a) and 3 (b) where the superposition theorem is invoked to find the contribution to the resultant output voltage made by each generator.

If, in order to save space, we use detached suffixes instead of the full impedance symbols the partial responses are found to be

$$\frac{v_a}{Ae} = \frac{38\,(57 + 67 + 56)}{8\,(2 + 3)\,(57 + 67 + 56) + (42 + 23 + 34)\,(85 + 86 + 57 + 56 + 76)}$$

$$\frac{v_b}{Ae} = \frac{68\,(42 + 23 + 34)}{8\,(5 + 6)\,(42 + 23 + 34) + (76 + 65 + 75)\,(82 + 83 + 42 + 23 + 34)}$$

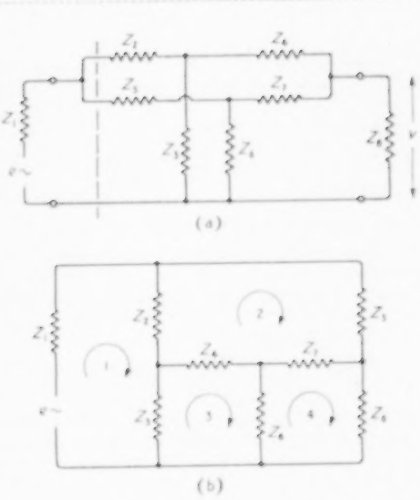


Fig. 1. *Parallel-connected T networks (a) and their meshes (b).*

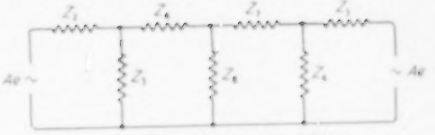


Fig. 2. *Equivalent circuit of Fig. 1.*

If the consequent expression for $(v_a + v_b)/e$ is compared with that for v/e obtained from Equ. (1) it will be found that

$$A = \frac{D'}{D} \qquad \ldots\ldots\ldots\ldots \quad (2)$$

where D' is the determinant of the original network when $Z_1 = 0$. The process may be quite generally applied to any number of quadripoles in parallel. The common pair of terminals at the output side is left untouched while at the input side each 'channel' is given its own generator of e.m.f. calculable from Equ. (2). The equivalence is shown in Fig. 4.

The device is most convenient when the generator feeding the quadripoles has zero internal impedance for then $A = 1$ and the operations required to find the transfer response are,

(a) with all the partial generators shorted except one find the partial response of the network to that generator. The denominator of

MS accepted by the Editor, October 1949

the expression when arranged to be present to a degree equal to the number of original meshes is the determinant of the network and does not need to be evaluated again.

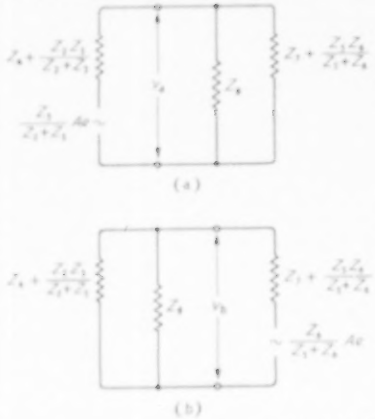
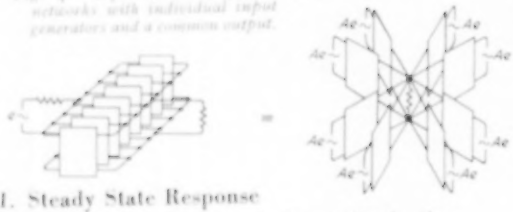


Fig. 3. *Reduction of circuit of Fig. 2 by the super-position theorem.*

(b) Find the partial numerators in the same way for each generator in turn. This can often be done by inspection.

The overall response of the network is the sum of the partial numerators divided by the common determinant. The advantage of the method lies in the fact that rearranging the network as a two-mesh circuit does not alter the value of the determinant and the latter is now calculable as a second-order array instead of the original higher-order expression.

Fig. 4. *Equivalence of paralleled quadripoles to networks with individual input generators and a common output.*



1. Steady State Response

As an example of the method we will take the parallel-T RC network of Fig. 5 (a) rearranged according to our scheme in Fig. 5 (b). Considering first the left-hand generator and using Thévenin's theorem we have,

$$\frac{v'}{e} = \frac{\frac{R}{R+Z}}{\frac{(16R^3+8RZ)(R+Z)}{(R+Z)(16R^2+8RZ)+(4R+Z)(Z^2+2RZ)}}$$

$$\frac{v'}{e} = \frac{16R^3+8R^2Z}{D} \quad \ldots \quad \ldots \quad (3)$$

similarly for the right-hand generator,

$$\frac{v''}{e} = \frac{Z^3+2RZ^2}{D}$$

whence

$$\frac{v}{e} = \frac{16R^3+8R^2Z+2RZ^2+Z^3}{16R^3+32R^2Z+14RZ^2+Z^3}$$

An alternative and possibly preferable method is to consider Fig. 5 (b) as a two-mesh circuit in which the numerator of the partial response to the left-hand generator is $B_{12}Z_0$ where Z_0 is the impedance seen to the right of the dotted line. In this case, by inspection, $B_{12} = R$ and Z_0 is given by $(16R^2+8RZ)/(4R+Z)$.

$$(4R+Z)\,B_{12}Z_0 = 16R^3+8R^2Z \quad \ldots \quad (4)$$

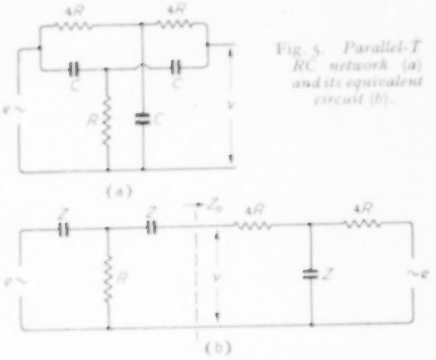


Fig. 5. *Parallel-T RC network (a) and its equivalent circuit (b).*

The reason for the above form is that the determinant of the network is also most neatly expressed when multiplied by $(4R+Z)$. Hence the numerator of the partial response is given by the right-hand side of Equ. (4) and the other partial response is found in a similar manner.

2. Transient Response

The splitting of a network into component channels affords a clear picture of its behaviour under transient conditions. Using the same example as before we can write Equ. (3) as

$$\frac{v'}{e} = \frac{-jx^3-\sqrt{2}x^2}{-jx^3-4\sqrt{2}x^2+7jx+\sqrt{2}}$$

where $x = \sqrt{8CR}$ is the normalized frequency variable. If we now substitute s/ω_0 for jx,

$$\frac{v'(s)}{e} = \frac{s^3+\sqrt{2}\omega_0^2}{s^3+4\sqrt{2}s^2\omega_0+7s\omega_0^2+\sqrt{2}\omega_0^2}$$

$$= \frac{s^2}{s^2+3\sqrt{2}\omega_0+\omega_0^2}$$

If for e we write $1/s$, the operational form of

Unit Function, and consult a table of transforms,

$$v'(t) = 1.067 \exp(-4\omega_0 t) - 0.067 \exp(-0.25\,\omega_0 t)$$

The coefficients of $\omega_0 t$ in the above expression are actually $-(3 \pm \sqrt{7})/\sqrt{2}$ or 3.993, 0.2506 but the approximations seem justified on the grounds of elegance. In the same way the partial transient response of the other channel is

$$v''(t) = 1 + 0.067 \exp(-4\omega_0 t) - 1.067 \exp(-0.25\omega_0 t)$$

The resultant transient response of the whole circuit is

$$v(t) = 1 + 1.135 \exp(-4\omega_0 t) - 1.135 \exp(-0.25\,\omega_0 t) \quad \ldots \quad (5)$$

This curve and the above components are plotted in Fig. 6. Here we have deliberately separated the response into two components to show the physical action within the circuit. In practice Equ. (5) would be written down more directly from the operational form of the complete response.

Equ. (5) is interesting in the present example in that although it is the response of a three-mesh network it involves only two exponential terms. The reason would appear to be connected with the fact that when the network is adjusted to give a complete null at one frequency, as in the present case, then the high-pass and low-pass channels must have equal time constants.

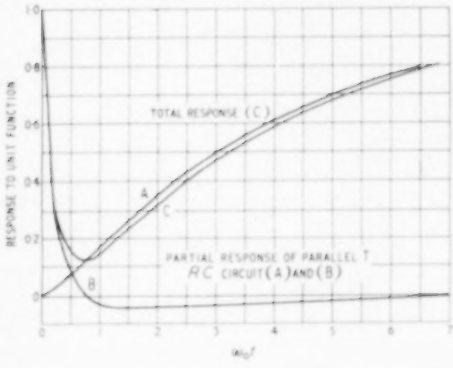


Fig. 6. *Partial and total responses of the network of Fig. 5 to a unit step.*

The mode of operation of parallel-channel circuits is often difficult to explain and the present analysis gives a method of at least describing their structure. The overall response of a parallel-channel network when fed from a zero-impedance generator is the sum of the individual responses of the separated channels when each is terminated on the load side by the short-circuit input impedance of all the other channels in parallel.

3. Impedance Calculations

The method may also be used for finding the input impedance of multi-channel networks. There is, however, one feature which should be pointed out. While any single generator is feeding the network it is putting current through the temporarily passive meshes belonging to other generators and thus reducing their effectiveness. For the previous example, in the equivalent circuit of Fig. 5 (b), for the left-hand generator, we have for unit applied voltage,

$$D = \begin{vmatrix} R+Z & -R \\ -R & 5R+Z+\dfrac{4RZ}{4R+Z} \end{vmatrix}$$

$$(4R+Z)\,D = 16R^3 + 32R^2Z + 14RZ^2 + Z^3$$

$$(4R+Z)\,B_{11} = 20R^2 + 13RZ + Z^2$$

$$(4R+Z)\,B_{12} = R(4R+Z)$$

$$\text{input current} = \frac{20R^2 + 13RZ + Z^2}{D} = I_1$$

$$\therefore \text{ current in second mesh} = \frac{R(4R+Z)}{D}$$

$\therefore$ current through shorted generator loop is

$$\frac{R(4R+Z)}{D} \cdot \frac{Z}{(4R+Z)} = \frac{RZ}{D} = I_2$$

In the same way for the other generator,

$$\text{input current} = \frac{4R^2 + 7RZ + 2Z^2}{D} = I_3$$

$\therefore$ current through shorted-generator loop

$$= \frac{RZ}{D} = I_4$$

Total input current to original network

$$= I_1 + I_2 + I_3 + I_4 = I_0$$

input impedance

$$= \frac{1}{I_0} = \frac{16R^3 + 32R^2Z + 14RZ^2 + Z^3}{24R^2 + 18RZ + 3Z^2}$$

It is probable that the procedure is most useful in finding the impedance of complicated structures. Consider the network of Fig. 7 (a) which may be thought of as a variant on the "cube of one ohm wires" theme. In this case we have a prism and the symmetry which aids the solution of the other problem is lacking. This circuit has the advantage however that it can be squashed flat as at Fig. 7 (b), rearranged as at (c) and finally given our form in (d). In this particular instance, with equal resistances the problem is also fairly easy if the star-mesh transformation is used but in the general case with unequal complex impedances the transformation is very laborious while our method remains fairly simple. In Fig. 7 (c) the method

should be noted of untwisting lattice arms and feeding their ends from a generator of reversed polarity.

Conclusion

The analysis of a particular class of networks, namely those consisting of a number of channels in parallel, fed from a common zero-impedance generator, is simplified by the device of replacing the one generator by a number of identical generators. Since the total current flowing through the original generator can produce no modification of the voltage applied to the network we can split off these separate generators and allot them to each channel. Applying the superposition theorem then reduces the problem to adding the responses of a number of single-mesh circuits. The procedure has also been found helpful in finding the input impedance of circuits which prove to be somewhat intractable by conventional methods.

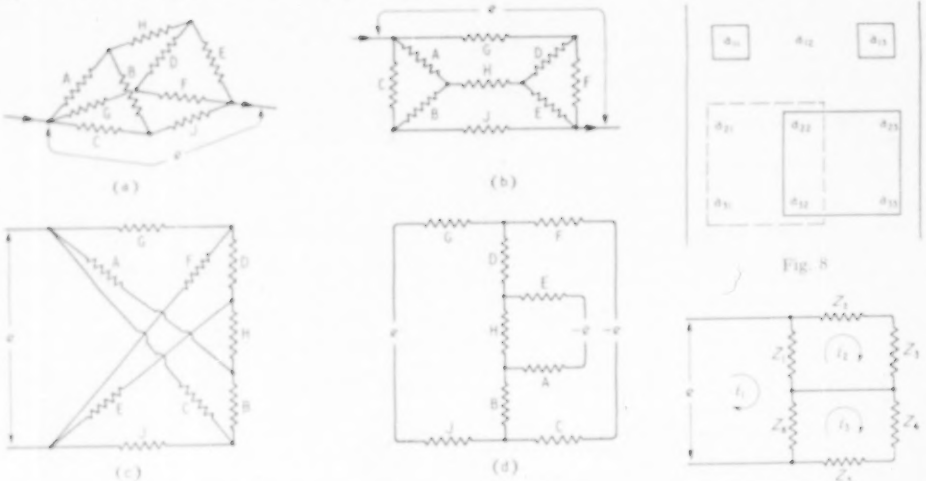


Fig. 7. *Variant of "cube of one-ohm wires" (a); squashed flat (b); re-arranged (c) and brought to its final form with independent generators (d).*

Fig. 8

Fig. 9

APPENDIX

The Use of Determinants in Network Analysis.

Network problems involve the solution of simultaneous equations and unless this is systematized the work becomes very tedious. Consider the equations

$$a_{11}x + a_{12}y = h_1 \quad \ldots \quad (6)$$

$$a_{21}x + a_{22}y = h_2 \quad \ldots \quad (7)$$

To find x multiply (6) by a_{22}, (7) by a_{12} and subtract (2) from (1), then

$$(a_{11}a_{22} - a_{12}a_{21})\,x = a_{22}h_1 - a_{12}h_2$$

i.e., $$x = \frac{a_{22}h_1 - a_{12}h_2}{a_{11}a_{22} - a_{12}a_{21}}$$

and y is given by a similar expression. The denominator of the right-hand side may be found by writing the coefficients in an array

$$\begin{vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{vmatrix}$$

and cross-multiplying so that products are taken diagonally to the right, positive downwards and negative upwards. To find the numerator we use the array

$$\begin{vmatrix} h_1 & a_{12} \\ h_2 & a_{22} \end{vmatrix}$$

in which the right-hand side of the equation has been substituted for the column containing the variable to be found. If we now solve a third-degree equation by the usual methods and set up an analogous array of coefficients we find that the rules for expanding this array are slightly more complicated but will now apply to an array of any order. Such an array is called a determinant and for a third-degree equation would be

$$\begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{vmatrix}$$

If the variables here are x, y and z then by the ordinary way,

$$y = \frac{a_{11}h_2a_{33} - a_{11}h_3a_{23} - h_1a_{21}a_{33} + h_1a_{31}a_{23} + a_{13}h_3a_{21} - a_{13}a_{31}h_2}{a_{11}a_{22}a_{33} - a_{11}a_{32}a_{23} - a_{12}a_{21}a_{33} + a_{12}a_{31}a_{23} + a_{13}a_{32}a_{21} - a_{13}a_{31}a_{22}}$$

We can reconcile the first and last two products in both the numerator and denominator with our previous rules by thinking of them as a common factor times a second-order determinant. This is shown in Fig. 8. The middle pair in each case however need to have their signs reversed before they can be interpreted in this way. The "sub-arrays" concerned here are called minors and a rule is required to determine the sign which must prefix them when expanded to form the denominator or numerator of the root of an equation. This rule is as follows. If a minor is formed by striking out the i-th row and j-th column of a determinant then in

an expansion it must be multiplied by $(-1)^{i+j}$. A signed minor is called a cofactor. To find the denominator of a root these operations are performed on the determinant of the original equation and for the numerator on the same array but with the right side of the equation substituted as in the second-order case.

In solving a network problem the work is further reduced by the fact that the various elements in the determinant have a simple physical significance. This enables us to write down the determinant of a network without the necessity of setting up the equations. In the case of Fig. 9 if we go through all the usual steps with Maxwell's cyclic currents we arrive at an array,

$$\begin{vmatrix} Z_1+Z_6 & -Z_1 & -Z_6 \\ -Z_1 & Z_1+Z_2+Z_3 & 0 \\ -Z_6 & 0 & Z_4+Z_5+Z_6 \end{vmatrix}$$

The elements in the "positive" diagonal are respectively the mesh impedances of mesh 1, mesh 2, mesh 3. The other elements represent common or mutual impedances between the various meshes. For example Z_1, the element common to row 1 and column 2 or to row 2 and column 1 is the impedance common to mesh 1 and mesh 2. The negative sign is due to the fact that the current in these two meshes flows in opposite directions. In the majority of cases, there is only one source of e.m.f. in this circuit, hence $h_1 = e$ and the other h terms are zero. This simplifies the numerator of the expression for current; e.g.,

$$I_1 = \frac{eB_{11}}{D}$$

where B_{11} is the cofactor formed by striking out row 1 and column 1 and giving the minor so formed a positive sign. This gives a simple formula for input impedance,

$$Z_{in} = D/B_{11}$$

NEGATIVE-RESISTANCE CHARACTERISTICS

Graphical Analysis

By A. W. Keen, A.M.I.E.E., M.I.R.E.

1. Introduction

IN view of the dissipative character of resistive components of passive electrical networks it is appropriate that the property of negative-resistance should be attributed to active elements. The negative-resistance concept has been employed frequently in the literature in connection with oscillatory circuits, and from time to time descriptions have been given of the occurrence of portions of negative slope in the volt-ampere characteristics of otherwise passive devices.

The first comprehensive account of the subject was published in 1935 by E. W. Herold[1]. It had been demonstrated by G. Crisson[2] that positive feedback over a telephone repeater gave rise to negative-resistance effects and that these differed in kind according as the feedback voltage was directly related to the output voltage or the output current of the circuit. It is of interest to observe that a similar distinction was discovered later in the behaviour of amplifiers subject to negative feedback. Herold used this distinction as a basis for the classification of known negative-resistance devices and for the analysis of their properties.

In the present paper a qualitative study of negative-resistance characteristics will be undertaken with the object of finding a more suitable element for analysis than the inadequate idealized resistor of conventional linear-network theory. The element so derived allows synthesis of actual characteristics by the superposition of graphically simple slope functions and leads to equivalent networks which facilitate the understanding of the physical behaviour of negative-resistance devices and their performance in actual networks.

An approximation to the ideal unilateral characteristic chosen is provided by the diode valve so that, if a diode having a negative slope in its volt-ampere characteristic existed, actual negative resistors could be represented by networks containing both kinds of diode. Negative resistance effects are experienced in valves having three or more electrodes; these are examined and found to be accurately representable by combinations of unilateral positive and negative elements or their diode equivalents.

2. Actual Negative-Resistance Characteristics

The difference between the two kinds of negative resistance is clearly illustrated in a comparison of their volt-ampere characteristics; the examples shown in Fig. 1 are repeated from Herold's paper. The significant feature of the curves is their form, from which Herold deduced that the type shown at (a) is due to voltage control, while that at (b) indicates current as the controlling factor. Moreover he noted that the relationship between them is analogous to that between resistance and conductance; i.e., a reciprocal one.

It will be clear from Fig. 1 that the behaviour

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of the two kinds of resistor differs not over the range of negative slope but at the ends of this part of the characteristic. Accordingly, if the voltage range over which the negative slope occurs could be extended indefinitely the two types would become indistinguishable except in the magnitude of their slope. Conversely, if this range could be reduced to zero the negative resistance property would vanish. These two transformations leave the resistance purely negative and entirely positive respectively and suggests that the actual resistance contains both positive and negative elements which predominate alternately over the voltage axis in the voltage-controlled type and over the current axis in the current-controlled case ; also that the two types correspond to fundamentally different combinations of pure positive and negative portions.

A feature of both characteristics, whose importance has not been adequately recognized in the literature, is the inequality of the absolute (E/I) and differential (dE/dI) values of the resistor. This discrepancy implies non-linearity of the resistor (*i.e.*, functional dependence upon voltage or current) and is an essential feature of resistors whose characteristics contain both positive- and negative-going portions. The characteristics possessed by certain screen-grid valves, as illustrated by Fig. 2, shows that both positive and negative absolute resistance may be accompanied by either positive or negative differential resistance (cf. points 1-4) at any given operating point.

Fig. 1. *Negative-resistance characteristic due to voltage control (a) and current control (b).*

Over the current range occupied by the negative slope of Fig. 1(a) there are, within the defined range of the characteristic, three values of applied voltage corresponding to each value of current. Accordingly, stability requires that the negative resistor be energized by a constant-voltage generator (i.e., one of zero internal impedance) for, if sufficient resistance is present in the generator, the current drawn from it may cause the p.d. developed between the resistor terminals to shift over more than one of the permissible values. The required generator characteristic may be approached by application of negative voltage feedback ; a voltage proportional to the p.d. between the resistor terminals is applied to the voltage source in such a manner that fluctuations of its output voltage tend to be self-cancelling

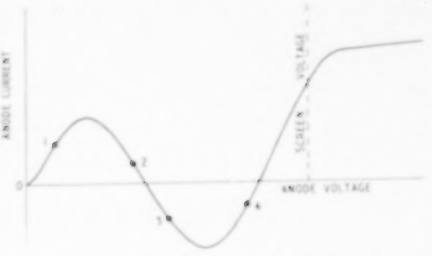

Fig. 2. *Characteristic of a screen-grid valve at constant control-grid voltage.*

and the output impedance is correspondingly reduced. Analogously, the multi-valued nature of the current in the characteristic of Fig. 1(b) over the voltage range occupied by the negative slope requires (ideally) a constant-current source (i.e., one of infinite internal impedance) such as may be approximated in practical generators by the application of heavy negative current feedback.

The foregoing brings out the need in an idealized negative resistor of the following characteristics :—

(i) Absence of portions in the volt-ampere characteristic having positive slope.

(ii) Possibility of inequality of absolute and differential values of resistance.

(iii) Capability of association with idealized positive resistors in such a manner that accurate equivalents of actual resistors may be synthesized. On the other hand the idealized resistor should have, at least to a fair approximation, a frequently occurring practical equivalent. Ideally the two types of pure resistance should be corresponding special cases of a more general idealized resistor.

3. Modified Ideal Positive Resistor

The volt-ampere characteristic of the idealized resistor of conventional network theory is essentially linear, the absolute and differential resistance values being identical for all values of impressed voltage or current. Analytically this restriction confines the characteristic to the first and third quadrants of the volt-ampere plane, for if it had a non-zero intercept with either axis the equality of actual and differential resistances would be destroyed and the resistor would be (electrically) non-linear. The behaviour of the linear resistor is bilateral (i.e., independent

of the polarity of the impressed quantity), as shown in Fig. 3. The graphical criterion of bilaterality involves successive rotation of the volt-ampere characteristic about the axes $i = 0$, $e = 0$ (in either order), which should leave the characteristic unchanged, and is useful in the analysis of complex cases.

The simple characteristic just described is inadequate for the analysis of resistors of the type under consideration since any finite series-parallel combination of linear elements cannot produce a non-linear resultant. Moreover nothing is gained in this respect by assigning the idealized pure negative resistor a characteristic of the same type as Fig. 3 but with negative slope, as discussed, for example by D. M. Tombs[3].

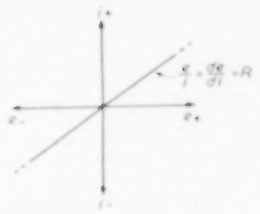

Fig. 3. *Characteristic of ideal positive resistor.*

Analytically the characteristic of Fig. 3 (or its negative-slope equivalent) needs only displacement from the origin to introduce electrical non-linearity but an element having such a characteristic is not available in useful two-terminal form since for physical reasons e and i must pass through zero together. As a result the intercept must be introduced effectively.

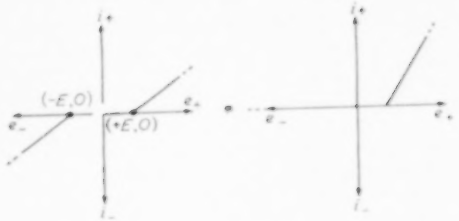

Fig. 4. *Symmetrical modified characteristic of a positive resistor (a), unilateral modified characteristic (b).*

The obvious method of allowing i to be a function containing higher powers of e than the first (or vice versa when i is the independent variable) will be discarded because of the difficulty, both graphically and analytically, of handling series-parallel combinations of such elements. Instead the characteristic of Fig. 3(a) will be modified by expanding the point at the origin over the segment of the abcissa bounded by the points $(-e, 0)$, $(+e, 0)$. It will be obvious that if this expansion is not performed symmetrically the bilateral property will be lost [See Fig. 4(a)]. On the other hand practical resistors generally have characteristics that are not bilaterally symmetrical and may even be entirely unilateral. Accordingly the 'broken' characteristic of Fig. 4(a) will be modified to the unilateral form shown at (b) to obtain a more versatile element which needs two parameters for its specification: (i) the potential at which the discontinuity occurs and (ii) the value (magnitude and sign) of its slope.

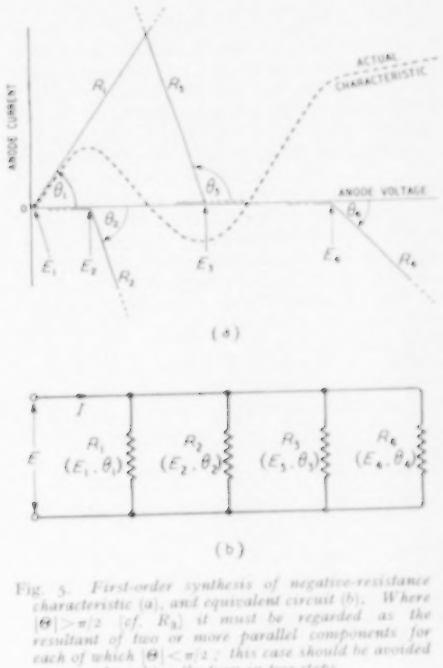

Fig. 5. *First-order synthesis of negative-resistance characteristic (a), and equivalent circuit (b). Where $|\theta| > \pi/2$ (cf. R_3) it must be regarded as the resultant of two or more parallel components for each of which $|\theta| < \pi/2$; this case should be avoided by taking the turn in two steps.*

4. Analysis of Complex Resistors

It will be clear that characteristics of the form of Fig. 1(a) are readily synthesized by the superposition of suitably chosen slope functions of the type shown in Fig. 4(b), while the current-controlled case illustrated by Fig. 1(b) may be dealt with similarly after inversion. In both cases the degree of approximation may be improved without limit by increasing the number of slope functions employed; fortunately it is worst at the turning points, which are avoided in practical applications for stability reasons.

A first approximation to the characteristic of Fig. 2 requires four slope functions, two of each sign, as shown in Fig. 5(a). It will be noted that the method of synthesis just described involves only direct superposition of the basic functions; accordingly, actual negative resistors may be represented by simple combinations of the idealized unilateral resistor. In the voltage-controlled case the elements add in parallel to give the required resultant current, while in the current-controlled case the elements add in series to give the resultant voltage. The equivalent network so derived is shown for the first case in Fig. 5(b).

5. Analysis of Valve Characteristics

The unilateral element derived in Section 3 is physically appropriate to electronic circuits, since an approximate equivalent exists in the hard diode valve. This is shown in Fig. 6(a) together with the corresponding representation [Fig. 6(b)] of the bilateral characteristic of Fig. 4(a). The value of this equivalence is limited from the point of view of actual synthesis from separate elements by the fact that the negative counterpart of the ordinary (positive) diode is not available as a distinct element. On the other hand, it is of importance in bringing out the existence of such elements in association with positive diodes in more complex valves. Thus equivalent networks, containing, in general, both positive and negative diode constituents, may be derived for the more complex valves and, in reducing the latter to combinations of the same basic elements, bring out clearly their physical behaviour and relative characteristics and point to the possibility of replacing the more complex types by two or more simpler types.*

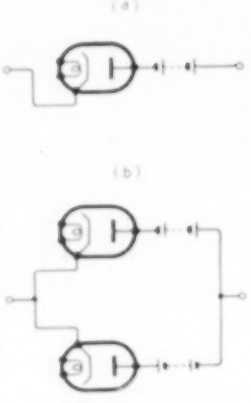

Fig. 6. *Illustrating the use of diodes to obtain the characteristic of Fig. 4.*

When a positive (with respect to cathode) potential is applied to an electrode of a valve, current is drawn from an interior space charge together with corresponding components initiated by other electrodes, the whole forming the total 'space' current. On approaching the electrode concerned this component may be absorbed (i.e., collected), reflected (or effectively so, as when secondary emission occurs) or transmitted (i.e., allowed to pass on to a succeeding electrode), as illustrated by Fig. 7. In an equivalent network both reflection and transmission require negative admittance to be attributed to the paths taken by the reflected and transmitted components.

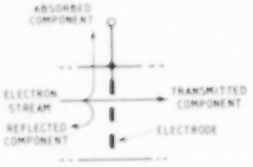

Fig. 7. *The components of electron current in a valve are shown.*

It is interesting to compare the network of Fig. 5(c) with the actual valve whose anode characteristic it represents. The tetrode concerned may, from the point of view of the anode-cathode terminals, be regarded as a complex 'diode'; i.e., one whose characteristics are modified in a (generally) complex manner by the introduction of the intermediate electrodes. Accordingly, the equivalent network of idealized positive and negative diodes and their associated generators may be regarded as a transformation of the actual 'diode.' In this respect the slope analysis provides an aid to the understanding of the physical behaviour of the tetrode valve.

The possibility of extending this method of treatment to three-terminal devices may be demonstrated by using the triode valve as an example. Normally the grid is biased negatively to prevent grid current flow and the entire space current is collected by the anode. To a first approximation the currents are:

$$i_a = (\mu/r_a)V_{cg} + (1/r_a)V_{ca} \quad [i_a \geqslant 0]$$

$$i_g = 0.$$

The anode current may, therefore, be resolved into two unilateral slope functions

$$i_a\,(g) = (\mu/r_a)\,V_{cg} \quad [i_a(g) \geqslant 0]$$

$$i_a\,(a) = (1/r_a)\,V_{ca} \quad [i_a(a) \geqslant 0]$$

and, correspondingly, the valve contains two positive diodes, one between cathode and grid and the other between cathode and anode, the former having a slope μ times that of the latter. It has been shown[7] that, ignoring space-charge considerations,

$$\mu = c_{cg}/c_{ca}$$

where c_{cg} = cathode-grid capacitance

* It may be mentioned that the characteristic of Fig. 4(b) has frequently been used in the analysis of networks containing diodes, and the analytical difficulty of dealing with the discontinuity has been overcome by the use of suitable transforms. Thus, the unilateral characteristic may be represented by the product of a step voltage of the form of Heaviside's $U(t)$ Function and the characteristic of Fig. 3. Alternatively, where the unilateral resistor need be represented over a limited voltage range, the characteristic of Fig. 3 may be multiplied by a square wave, thereby allowing Fourier Series rather than Fourier Integral analysis[6, 7]. Again, the discontinuity may be taken out by Laplace transformation, which (apart from a pole at zero) converts the function into a relatively simple algebraic function of the complex variable[8].

and c_{ca} = cathode-anode capacitance.

In addition, the failure of the grid to collect current requires the connection of a third element, a negative 'image' of the grid-cathode diode, between grid and anode. The complete equivalent network is shown in resistance form as Fig. 8. It differs from conventional equivalents in being of transmission form.

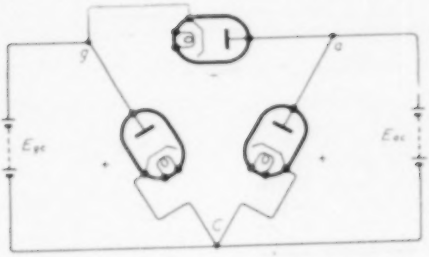

Fig. 8. *Diode equivalent circuit of a triode valve. The hypothetical "negative" diode assumes such an impedance value that the required operating condition (usually zero current) obtains in the grid-cathode circuit.*

When the triode is employed as an amplifier the steady potentials (V_{gc}, V_{ca}) applied to its electrodes are chosen to prevent grid current flow and keep anode current from falling to the discontinuity in the anode characteristic on negative excursions of the input signal. Moreover the anode characteristic not being linear [it is more accurately represented by

$$i_a = \{(\mu/r_a)\ V_{gc} + (1/r_a)\ V_{ca}\}^{3/2}$$

than by the previous equation] and the transition from anode current cut-off to the 'linear' regime being, relatively gradual, there is, consequently, an optimum mean anode current for minimum non-linearity and the signal input must be restricted in amplitude to keep distortion to small proportions. Under these conditions the r_a used in the above relationships will differ in its absolute and differential values but, provided the latter is preferred and the valve operated substantially linearly the network of Fig. 8 may also be employed to represent the alternating-current behaviour of the valve. Since the anode circuit is loaded it is necessary to add in the grid-anode branch an impedance of such a value that the zero grid-current condition is preserved. For the conventional amplifier (i.e., grid input–anode output) this value will be the parallel resultant of r_a and the load impedance. This additional element, being characteristic of the external network rather than of the valve itself may be termed the 'reflected' component of the grid-anode impedance. Its presence may be shown to be necessary in maintaining zero total impedance around the mesh formed by the valve elements and the external impedances.

6. Conclusion

The methods and ideas introduced in the foregoing are capable of extension to more complex valve types than the triode and lead to developments which, it is hoped, will be dealt with in subsequent papers.

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X-CUT QUARTZ CRYSTAL

Equivalent Circuit as an Ultrasonic Generator

By F. M. Leslie, M.Sc., Ph.D.

(*Electrical Engineering Dept., Leeds University*)

SUMMARY.—A new equivalent circuit for a crystal driving a mechanical load is devised in terms of an electrical transmission line instead of the usual lumped components of inductance and capacitance.

Introduction

THE general theoretical treatment of crystal ultrasonic generators has received a fair amount of attention and the presentation of the equivalent electrical circuit in terms of lumped components of inductance and capacitance is now well known. For understanding the behaviour of the generator the usual equivalent circuit is perhaps not quite so simple as it might be, and with this in mind a new equivalent circuit has been devised which lends itself very readily to the conditions under which the crystal operates when employed for ultrasonic generation.

List of Symbols

C_0	=	capacitance of the crystal when clamped.
E	=	voltage applied to the crystal.
f, f_0	=	frequency.
I	=	current to the crystal.
j	=	$\sqrt{-1}$.
m	=	a constant.
S	=	stress in the plane distance x from one face.
S_1, S_2	=	stress at the crystal face.
t	=	crystal thickness.
v	=	velocity of propagation.
x	=	distance measured from one face of the crystal.
$Z_m, Z_{m'}$	=	electrical impedance.
z_0	=	characteristic impedance of the crystal.
z_1, z_2	=	mechanical load impedance.
β	=	phase shift constant.
ξ'	=	velocity of the plane distance x from one face.
ξ'_1, ξ'_2	=	velocity of the crystal face.

Equivalent Electrical Circuit

The general theoretical treatment of crystals is adequately dealt with in the literature[1, 2, 3] and the fundamental equations which will be employed in determining the equivalent circuit for a crystal having unit area are as follows, the losses in the crystal being ignored :—

$$\xi' = \xi'_1 \cos \beta x - j\left(\frac{S_1 + mE}{z_0}\right) \sin \beta x \quad \ldots \quad (1)$$

$$(S + mE) = (S_1 + mE) \cos \beta x - jz_0 \xi'_1 \sin \beta x \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

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$$I = j2\pi f C_0 E + m(\xi'_1 - \xi'_2) \quad \ldots \quad \ldots \quad (3)$$

Fig. 1 depicts a typical crystal, the electrodes being on the major surfaces and the distance x measured to the right of the left-hand face. As is usual in the development of the equivalent lumped circuit, the presence of subsidiary vibrational modes will be ignored. If z_1 and

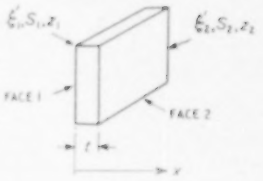

Fig. 1. *Form of typical crystal.*

z_2 are the mechanical loads on the two faces then $-\xi'_1 S_1 = z_1$ at $x = 0$ and $\xi'_2 S_2 = z_2$ at $x = t$, thus equation (2) may be written

$$\xi'_2 = \frac{z_1}{z_2}\xi'_1 \cos \beta t + \frac{mE}{z_2}(\cos \beta t - 1) - j\xi'_1 \frac{z_0}{z_2} \sin \beta t \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

Putting $x = t$ in equation (1) and then combining with equation (4),

$$\xi'_1 = \frac{\dfrac{mE}{z_2}(\cos \beta t - 1) + \dfrac{jmE}{z_0} \sin \beta t}{(1 + z_1/z_2)\cos \beta t + j(z_1/z_0 + z_0/z_2) \sin \beta t} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

From equation (1)

$$(\xi'_1 - \xi'_2) = \xi'_1 [(1 - \cos \beta t) - jz_1/z_0 \sin \beta t] + j\frac{mE}{z_0} \sin \beta t \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

Substituting equation (5) in equation (6),

$$(\xi'_1 - \xi'_2) = mE\left[\frac{2(\cos \beta t - 1) + j(z_2/z_0 + z_1/z_0) \sin \beta t}{(z_1 + z_2)\cos \beta t + j\left(z_0 + \dfrac{z_1 z_2}{z_0}\right) \sin \beta t}\right] \quad (7)$$

It is seen from equation (3) that the input impedance to the crystal can be considered as made up of two components in parallel. One component due to the capacitance C_0 and the other due to the motion of the crystal, this latter component will be termed the motional impe-

dance. From equation (7) it follows that the motional impedance for unit area of the crystal will be given by,

$$Z_m = \frac{E}{m(\dot{\xi}_1 - \dot{\xi}_2)} =$$

$$\frac{1}{m^2}\left[\frac{(z_1+z_2)\cos\beta t + j\,(z_0 + z_1z_2/z_0)\sin\beta t}{2\,(\cos\beta t - 1) + j(z_2/z_0 + z_1/z_0)\sin\beta t}\right] \quad (8)$$

or

$$Z_m = \frac{z_0}{m^2}\left[\frac{(z_1+z_2) + j\left(z_0 + \frac{z_1z_2}{z_0}\right)\tan\beta t}{2z_0\left(\frac{\cos\beta t - 1}{\cos\beta t}\right) + j(z_1+z_2)\tan\beta t}\right] \quad (9)$$

Consider now the input impedance to an electrical transmission line of length t having a phase shift constant β, characteristic impedance $z_0/4m^2$ and terminated by a load $\frac{z_1+z_2}{4m^2}$. The input impedance to the line would be,

$$Z_{me} = \frac{z_0}{m^2}\left[\frac{(z_1+z_2) + jz_0\tan\beta t}{4z_0 + 4j\,(z_1+z_2)\tan\beta t}\right] \quad .. \quad (10)$$

Suppose now that $\beta t \approx \pi$ and further that,

$$z_0 \gg \frac{z_1z_2}{z_0}$$

$$z_0 \gg (z_1+z_2)\tan\beta t$$

then equations (9) and (10) become identical, equation (9) reducing to

$$Z_m = \frac{1}{4m^2}[(z_1+z_2) - jz_0\Delta\theta] \quad .. \quad .. \quad (11)$$

where

$$\Delta\theta = \frac{2\pi\Delta f t}{v}$$

$$\Delta f = f_0 - f$$

and the resonant frequency f_0 is given by

$$f_0 = v/2t$$

With regard to the requirement that $z_0 \gg z_1z_2/z_0$ this is readily fulfilled in the case of a quartz crystal, and for example, water loads [$z_1 = z_2 = 1.5 \times 10^5$g/(cm^2 sec), $z_0 = 14.4 \times 10^5$ g/(cm^2 sec)], further, as $\beta t \approx \pi$ the second condition will also be satisfied. For an X-cut quartz crystal the constant m has a value $0.528 \times 10^5/t$ where t is in cm, expressing z_0, z_1 and z_2 in g/(cm^2 sec), then Z_m is obtained in statohms.

Thus, from the equivalence of equations (9) and (10) it follows that the behaviour of the loaded crystal in the vicinity of the resonant frequency follows very closely that of an electrical transmission line, provided the load impedances are not too great. The equivalent circuit in terms of a line is shown in Fig. 2.

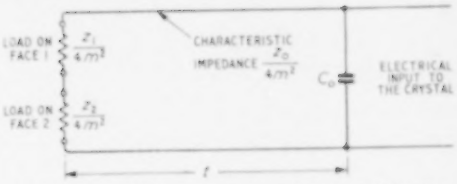

Fig. 2. *Equivalent transmission-line circuit for the crystal near resonance.*

Conclusion

An approximate equivalent circuit in terms of an electrical transmission line has been devised for the X-cut quartz crystal as used for ultrasonic generation. The equivalent circuit behaviour is almost identical with that for the crystal in the vicinity of resonance, provided the crystal-face loads are small, as they would be in the case of liquid loads. The equivalent circuit is considerably simpler than the usual lumped arrangement, and the effects of non-resonant operation or the coating of the crystal major surfaces with a thin metallic layer are readily interpreted from it.

Acknowledgment

The writer desires to express his thanks to Professor Carter for suggestions in the preparation of the paper, and to Imperial Chemical Industries Ltd. for their Fellowship.

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TRANSIENT RESPONSE CALCULATION

Use of Poisson Probability Tables

By J. E. Flood, B.Sc.(Eng).

THE usual criterion adopted for judging the transient response of an amplifier circuit is the response at the output of the amplifier when the input voltage is a unit step (i.e., a voltage which is zero when $t<0$ and is unity when $t>0$). The response to an input waveform of any other shape can, in general, be determined by means of Duhamel's integral[1]. The response to a unit step of some simple amplifier circuits having a number of identical stages can be expressed in terms of the Poisson exponential probability summation. Tables and charts of this function have been published, thus simplifying the calculation of the response of the amplifier circuits.

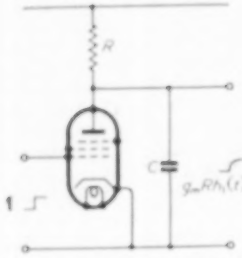


Fig. 1. *Simple resistance-coupled stage.*

(*Fig. 2 is on page 183.*)

1. Resistance-coupled Amplifier

The single-stage resistance-coupled pentode amplifier shown in Fig. 1 has an anode load resistance R, and C is the total stray capacitance between anode and earth.

The Heaviside operational expression for the output voltage when the input voltage is a unit step is

$$g_m R\, h_1(p)\,\mathbf{1} = g_m \frac{R}{1+pCR}\mathbf{1} = g_m R \frac{\alpha}{p+\alpha}\mathbf{1} \quad \ldots \quad (1)$$

where $\alpha = 1/RC$

This gives the well known result for the response as a function of time

$$g_m R\, h_1(t)\,\mathbf{1} = g_m R\,(1-\varepsilon^{-\alpha t}) \text{ for } t>0 \ldots \quad (2)$$

The response to a unit step of an amplifier having n similar stages is

$$(g_m R)^n h_n(p)\,\mathbf{1} = [g_m R\, h_1(p)]^n\,\mathbf{1}$$

$$= (g_m R)^n \left(\frac{\alpha}{p+\alpha}\right)^n \mathbf{1} \quad \ldots \quad (3)$$

It is shown in Appendix 1 that the response as a function of time is

$$(g_m R)^n\, h_n(t)\,\mathbf{1} \text{ where}$$

$$h_n(t) = 1 - \varepsilon^{-\alpha t}\left(1 + \frac{\alpha t}{1!} + \frac{\alpha^2 t^2}{2!} + \ldots + \frac{\alpha^{n-1} t^{n-1}}{(n-1)!}\right)$$

$$= 1 - \varepsilon^{-\alpha t} \sum_{r=0}^{n-1} \frac{\alpha^r t^r}{r!} \quad \ldots \quad (4)$$

Equation (4) is the expansion of the incomplete Gamma Function

$$\frac{1}{(n-1)!}\int_0^{\alpha t} \varepsilon^{-\alpha t}(\alpha t)^{n-1}\, d(\alpha t)$$

which has been tabulated by Pearson[2] for values of n up to 50. Equation (4) is also of the same form as the Poisson exponential probability summation.

It is shown in Appendix 2 that the probability $\{p_r(a)\}$ that an event will occur exactly r times in a large number of trials, for which a is the average number of occurrences, is

$$p_r(a) = \frac{a^r}{r!}\varepsilon^{-a} \quad \ldots \quad (5)$$

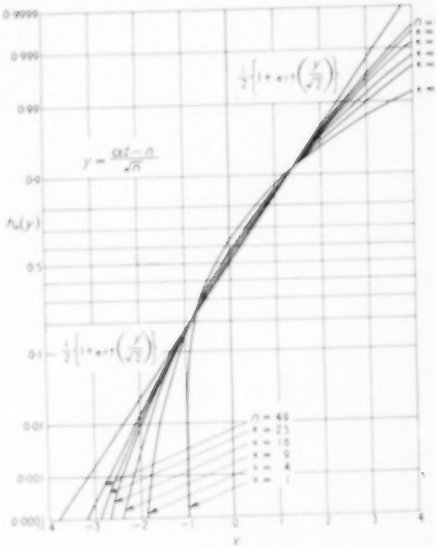


Fig. 3. *Response to a unit step of a resistance-coupled n-stage amplifier.*

MS accepted by the Editor, October 1949

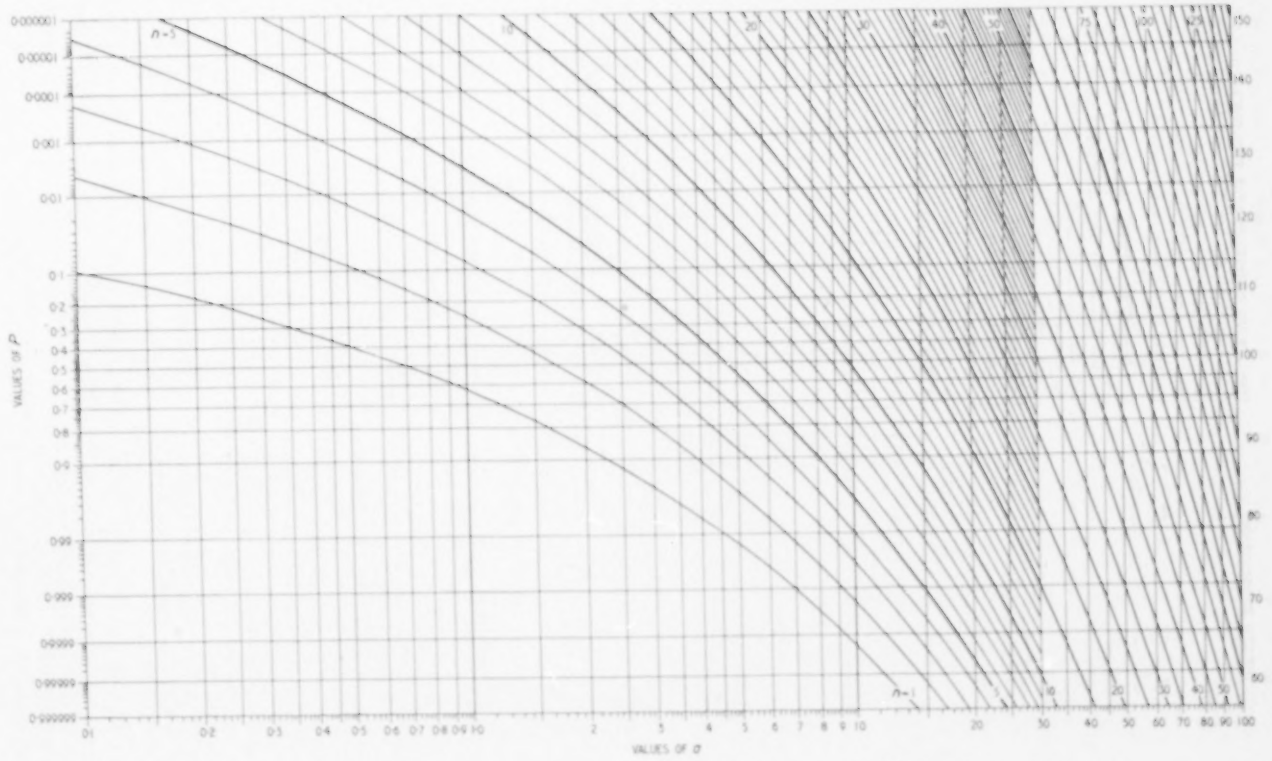


Fig. 2. *Probability curves showing Poisson's exponential summation* $P = 1 - \left[1 + \frac{a}{1!} + \frac{a^2}{2!} + \ldots + \frac{a^{n-1}}{(n-1)!}\right] e^{-a}$ *for the probability P that an event occurs at least n times in a large group of trials for which the average number of occurrences is a. A scale proportional to the normal probability integral is used for P, a logarithmic scale for a.*

and the probability that the event will occur at least n times is given by the summation

$$P_n(a) = \sum_{r=n}^{\infty} p_r(a)$$

$$= 1 - e^{-a}\left(1 + \frac{a}{1!} + \frac{a^2}{2!} + \ldots + \frac{a^{n-1}}{(n-1)!}\right) \quad (6)$$

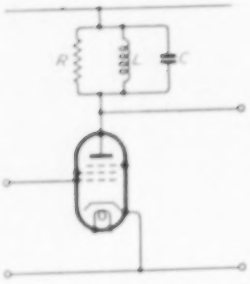
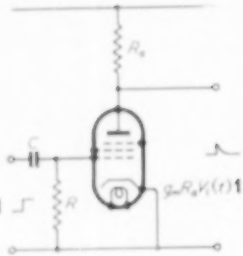


Fig. 4 (above). *Single tuned-circuit coupling.*

Fig. 5 (below). *Resistance-capacitance coupling.*

Fig. 6 (right). *Response to a unit step of an n-stage resistance-capacitance coupled amplifier.*



The expression for the response to a unit step of the n-stage resistance-coupled amplifier is seen to be identical in form with the Poisson exponential summation and so can be evaluated from the tables by Molina[3] or charts by Campbell[4]. Molina's tables give the values of both p_n and P_n. The chart reproduced as Fig. 2 (on page 183) enables the response of amplifiers to be simply determined for any number of stages up to 150 and values of αt up to 100.

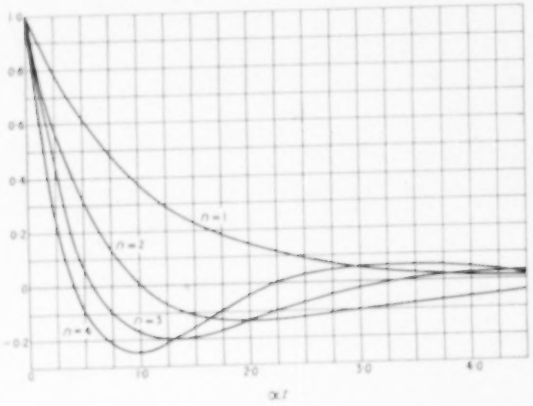
It is shown in Appendix 5 that when the number of stages is large, the response to a unit step is approximately given by

$$h_n(t) \approx \tfrac{1}{2}\left\{1 + \mathrm{erf}\left(\frac{\alpha t - n}{\sqrt{n}}\right)\right\}$$

Tables of the error function can be found in text-books on statistics[12, 13] and enable the response to be calculated approximately when the number of stages is large. Fig. 3 shows the above equation and the response calculated from equation (4) for different numbers of stages: the error function expression is seen to represent the response with increasing accuracy as the number of stages is increased.

2. Amplifier With Single-tuned Circuits

The circuit of the amplifier shown in Fig. 4 can be obtained from the circuit of Fig. 1 by means of the low-pass to band-pass transformation.[5] The envelope of the response of the band-pass circuit to an input of its mid-band frequency, amplitude-modulated by a unit step, is approximately the response to a unit step of the equivalent low-pass circuit. It has been shown[6] that the envelope of the response of



an amplifier with n identical tuned circuit stages to an input of their natural frequency, modulated by a unit step, is also given by equation (4), where $\alpha = 1/2RC = \omega_0/2Q$. The response can therefore be rapidly determined by means of the tables or charts.

3. Stages of Resistance-Capacitance Coupling

It is well known that the response to a unit step of the coupling circuit shown in Fig. 5 is given by

$$\left.\begin{aligned} v_1(t)\,\mathbf{1} &= \left[1 - h_1(t)\right]\mathbf{1} = e^{-\alpha t}\,\mathbf{1} \\ v_1(p)\,\mathbf{1} &= \mathbf{1} - h_1(p)\,\mathbf{1} = \frac{p}{p+\alpha}\,\mathbf{1} \end{aligned}\right\} \quad \ldots \quad (7)$$

where $\alpha = 1/RC$

The response of an n-stage resistance-capacitance coupled amplifier to an input consisting of a unit step is $(g_m R_a)^n v_n(t)\,\mathbf{1}$

where $v_n(p)\,\mathbf{1} = \left(\frac{p}{p+\alpha}\right)^n \mathbf{1}$

It is shown in Appendix 3 that

$$v_n(t) = e^{-\alpha t} \sum_{r=0}^{n-1} {}_{n-1}C_r (-1)^r \frac{\alpha^r t^r}{r!} \quad \ldots \quad (8)$$

$$= \sum_{r=0}^{n-1} {}_{n-1}C_r (-1)^r p_r(\alpha t) \quad \ldots \quad (9)$$

also $$v_n(t) = 1 + \sum_{r=1}^{n} {}_nC_r (-1)^r h_r(\alpha t) \quad \ldots \quad (10)$$

$$= 1 + \sum_{r=1}^{n} {}_nC_r (-1)^r P_r(\alpha t) \quad \ldots \quad (11)$$

where ${}_nC_r$ is the binomial coefficient

$$\frac{n \cdot (n-1) \ldots (n-r+1)}{r!}$$

Equation (9) is convenient for computation from the tables of the individual terms $p_r(a)$ and equation (11) is convenient for computation from the curves shown in Fig. 2. Fry[13] gives tables of the binomial coefficient ${}_nC_r$ for values of n up to 100. Fig. 6 shows $v_n(t)$ for values of n up to 4.

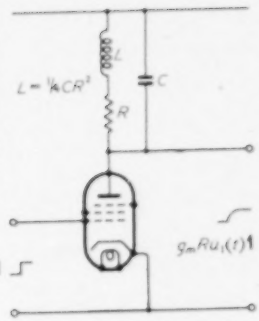


Fig. 7. *Critically-damped inductance-compensated stage.*

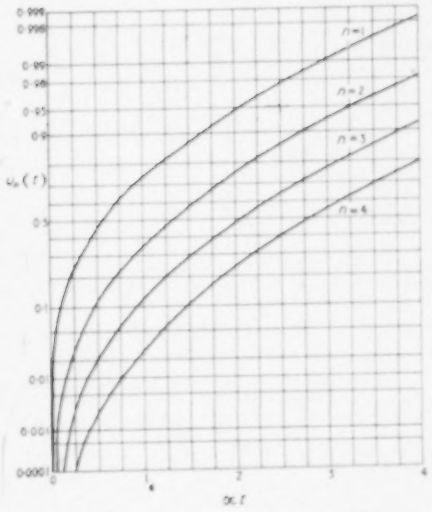


Fig. 8. *Response to a unit step of a critically-damped inductance-compensated n-stage amplifier.*

Equation (7) can often be used to represent the error in the output of a servo-mechanism, such as an automatic gain control, when a sudden change is made in the input.[14] Equations (8) and (10) therefore represent the error in the output of the nth servo of a chain of servo-mechanisms connected in tandem. For instance, if a sudden change is made in the input level of the pilot signal to a carrier telephone line containing n repeaters, each fitted with a pilot-operated automatic gain control, the change in the level of the output signal is given by $v_n(t)$. Although each servo operates without any overshoot when alone, the output from the nth servo-mechanism overshoots $n-1$ times before reaching the correct value.

4. Critically-damped Inductance-compensated Amplifier

The circuit is shown in Fig. 7. It has been shown that the response to a unit step has the quickest build-up which is possible without overshoot when $L = \frac{1}{4}CR^2$, which is the condition

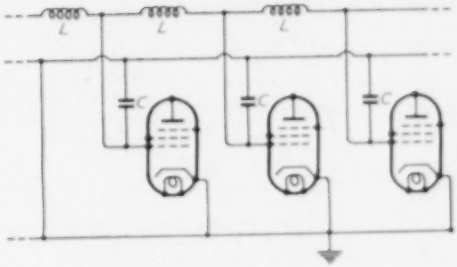


Fig. 9. *Filter-coupled amplifier.*

for critical damping. The response to a unit step is then[7]

$$g_m R\, u_1(t)\,\mathbf{1} = g_m R\,[1 - e^{-2\alpha t}(1 + \alpha t)]\,\mathbf{1} \quad (12)$$

where $\alpha = 1/CR = R/4L$

it is shown in Appendix 4 that the response of an amplifier having n identical stages is

$$u_n(t)\,\mathbf{1} = 1 - e^{-2\alpha t} \sum_{r=0}^{2n-1} {}_nb_r \frac{\alpha^r t^r}{r!}, \; t > 0 \quad \ldots \quad (13)$$

where ${}_nb_0 = 1$, ${}_nb_{2n-1} = 2^n$,

and ${}_nb_r = 2_{n-1}b_{r-2} + {}_{n-1}b_{r-1}$

$$\therefore\; u_n(t) = 1 - e^{-2\alpha t} \sum_{r=0}^{2n-1} {}_nb_r\, p_r(\alpha t) \quad \ldots \quad (14)$$

The values of $p_r(t)$ are readily obtainable from the tables and ${}_nb_r$ is easily calculated. Table 1 gives the values of ${}_nb_r$ for values of n up to 8 and Fig. 8 shows $u_n(t)$ for values of n up to 4.

5. A Constant-resistance Network

When a number of valves are to be connected together, a method of avoiding connecting all the valve capacitances in parallel is to connect a low-pass filter section between each pair of valves, the valve capacitances forming the shunt arms of the filter, as shown in Fig. 9. In order to make the delay distortion fairly small within the pass band, mutual inductance between adjacent coils is sometimes used to provide a mid-series derived type of filter[8]. The response to a unit step of any practical dissipationless filter circuit is, however, oscillatory[9], and so is the response of an 'ideal' filter[10].

In some applications it is necessary for the response of the coupling network to be free from overshoot, and a simple way of achieving this is to connect damping resistors across the coils of the filter. If a resistance equal to the design resistance of the network is connected in parallel with each inductance, the circuit of Fig. 9 becomes equivalent to a number of the constant-resistance sections shown in Fig. 10 connected in tandem. The response to a unit step of the constant-resistance network of Fig. 10 is

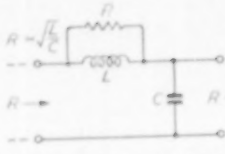


Fig. 10. *Constant-resistance network.*

$$\phi_1(p)\,\mathbf{1} = \frac{1/pC}{R + 1/pC}\,\mathbf{1} = \frac{1}{1 + pCR}\,\mathbf{1}$$

$$= \frac{\alpha}{p + \alpha}\,\mathbf{1} \quad \text{where } \alpha = 1/RC$$

$$= h_1(p)\,\mathbf{1} \quad \text{(equation 1)}$$

The response to a unit step of the constant-resistance network is seen to be the same as the response of a single-stage resistance-coupled amplifier. The response at the end of the nth section of the coupling network is therefore the same as the response of an n-stage resistance-coupled amplifier and is readily calculated from equation (4) by means of the tables or charts.

TABLE 1

Coefficients $_nb_r$

r \ n	1	2	3	4	5	6	7	8
1	1	2	3	4	5	6	7	8
2		3	6	10	15	21	28	36
3		2	7	18	35	56	84	120
4			8	30	75	148	258	414
5			4	32	105	256	518	932
6				20	96	336	882	1848
7				8	64	288	960	2640
8					32	192	768	2560
9					16	128	576	2048
10						64	384	1536
11						32	256	1024
12							128	768
13							64	512
14								256
15								128

Acknowledgment

Acknowledgment is made to the Engineer-in-Chief of the G.P.O. for permission to publish this paper. The writer's thanks are due to Mr. W. E. Thomson for his help and advice.

APPENDIX 1

Response to a Unit Step of a Resistance-coupled Amplifier

Let the response to a unit step of an amplifier having n similar stages be $(g_mR)^n\,h_n(t)\,\mathbf{1}$

Assume that $h_n(t) = 1 - e^{-\alpha t}\left[1 + \frac{\alpha t}{1!} + \frac{\alpha^2 t^2}{2!} + \ldots + \frac{\alpha^{n-1} t^{n-1}}{(n-1)!}\right]$

$$= 1 - e^{-\alpha t}\sum_{r=0}^{n-1}\frac{\alpha^r t^r}{r!} \qquad \ldots\ldots\ldots\ldots \quad (4)$$

$$\therefore h_{n+1}(t)\,\mathbf{1} = \frac{\alpha}{p+\alpha}\cdot h_n(t)\,\mathbf{1}$$

$$= \frac{\alpha}{p+\alpha}\left\{1 - e^{-\alpha t}\left[1 + \frac{\alpha t}{1!} + \frac{\alpha^2 t^2}{2!} + \ldots + \frac{\alpha^{n-1} t^{n-1}}{(n-1)!}\right]\right\}\mathbf{1}$$

But $f(p)\,e^{-\alpha t}g(t)\,\mathbf{1} = e^{-\alpha t}f(p-\alpha)\,g(t)\,\mathbf{1}$ by the shifting theorem[1]

$$\therefore h_{n+1}(t) = \frac{\alpha}{p+\alpha}\,\mathbf{1} - e^{-\alpha t}\frac{\alpha}{p}\left[1 + \frac{\alpha t}{1!} + \frac{\alpha^2 t^2}{2!} + \ldots + \frac{\alpha^{n-1} t^{n-1}}{(n-1)!}\right]\mathbf{1}$$

But $\frac{\alpha^r t^r}{r!}\,\mathbf{1} = \frac{\alpha^r}{p^r}\,\mathbf{1}$

$$\therefore h_{n+1}(t)\,\mathbf{1} = \frac{\alpha}{p+\alpha}\,\mathbf{1} - e^{-\alpha t}\frac{\alpha}{p}\left[1 + \frac{\alpha}{p} + \frac{\alpha^2}{p^2} + \frac{\alpha^3}{p^3} + \ldots + \frac{\alpha^{n-1}}{p^{n-1}}\right]\mathbf{1}$$

$$= \frac{\alpha}{p+\alpha}\,\mathbf{1} - e^{-\alpha t}\left[\frac{\alpha}{p} + \frac{\alpha^2}{p^2} + \frac{\alpha^3}{p^3} + \ldots + \frac{\alpha^n}{p^n}\right]\mathbf{1}$$

$$= (1 - e^{-\alpha t})\,\mathbf{1} - e^{-\alpha t}\sum_{r=1}^{n}\frac{\alpha^r t^r}{r!}\,\mathbf{1}$$

$$\therefore h_{n+1}(t) = 1 - e^{-\alpha t}\sum_{r=0}^{n}\frac{\alpha^r t^r}{r!}$$

$\therefore$ if equation (4) is valid for n stages, it is valid for $n+1$ stages. But it is well known for $n = 1$ and is simply proved for $n = 2$ and 3; therefore, it is valid for any number of stages.

APPENDIX 2

The Poisson Exponential Probability Summation

If the probability that an event will occur in any one trial is p_1 and a large number (m) of trials is made, then the average number of events (a) occurring in m trials is mp_1.

The probability that the event will occur in each of r trials is p_1^r and the probability that the event will fail to occur in the remaining $m-r$ trials is $(1-p_1)^{(m-r)}$. But the number of ways in which the event may happen exactly r times in m trials is $_mC_r = \frac{m(m-1)(m-2)\ldots(m-r+1)}{r!}$

$\therefore$ The probability (p_r) that the event will happen exactly r times in m trials is

$$p_r = {}_mC_r\, p_1{}^r\,(1-p_1)^{m-r}$$

But $p_1 = a/m$

$$\therefore p_r = {}_mC_r \left(\frac{a}{m}\right)^r \left(1-\frac{a}{m}\right)^{m-r}$$

$$= \frac{m(m-1)(m-2)\ldots(m-r+1)}{r!} \cdot \frac{a^r}{m^r}\left(1-\frac{a}{m}\right)^{m-r}$$

$$= \frac{a^r}{r!}\left(1-\frac{1}{m}\right)\left(1-\frac{2}{m}\right)\ldots\left(1-\frac{r-1}{m}\right)\left(1-\frac{a}{m}\right)^{-r}\left(1-\frac{a}{m}\right)^{m}$$

Since m is very large, the terms inside each bracket except the last tend to unity

$$\therefore p_r = \frac{a^r}{r!}\left(1-\frac{a}{m}\right)^m$$

But when m is very large, $\left(1-\frac{a}{m}\right)^m \to e^{-a}$

$$\therefore\ p_r = \frac{a^r}{r!}e^{-a} \qquad \ldots\ \ldots\ \ldots\ \ldots\ \ldots \quad (5)$$

which gives the probability that the event will occur exactly r times out of a large number of trials for which the average number of occurrences is a.

Let the probability that the event will occur at least n times in a large number of trials be P_n.

$$\therefore P_n = p_n + p_{n+1} + p_{n+2} + \ldots\ldots$$

$$= \sum_{r=n}^{\infty} p_r$$

But $\sum_{r=0}^{\infty} p_r$, the sum of all the possible chances, is equal to unity.

$$\therefore\ P_n = 1 - \sum_{r=0}^{n-1} p_r = 1 - e^{-a}\sum_{r=0}^{n-1}\frac{a^r}{r!} \qquad \ldots\ \ldots \quad (6)$$

APPENDIX 3

Resistance-capacitance Coupled Stages

The response to a unit step of a single coupling network is

$$\left.\begin{aligned} v_1(t) \rfloor\!\lfloor &= [1-h_1(t)] \rfloor\!\lfloor = e^{-\alpha t} \rfloor\!\lfloor \\ v_1(p) \rfloor\!\lfloor &= \frac{1}{p} \rfloor\!\lfloor - h_1(p) \rfloor\!\lfloor = \frac{\beta}{p+\alpha} \rfloor\!\lfloor \end{aligned}\right\} \qquad \ldots\ \ldots \quad (7)$$

$\therefore$ The response of an n-stage resistance-capacitance coupled amplifier is

$$(g_m R_a)^n\, v_n(t) \rfloor\!\lfloor$$

where $v_n(p) \rfloor\!\lfloor = \left(\frac{\beta}{p+\alpha}\right)^n \rfloor\!\lfloor$

But by the shifting theorem, $f(p) \rfloor\!\lfloor = e^{-\alpha t}\frac{p}{p-\alpha} f(p-\alpha) \rfloor\!\lfloor$

$$\therefore v_n(p) \rfloor\!\lfloor = e^{-\alpha t}\frac{p}{p-\alpha}\cdot\frac{(p-\alpha)^n}{p^n} \rfloor\!\lfloor$$

$$= e^{-\alpha t}\left(1-\frac{\alpha}{p}\right)^{n-1} \rfloor\!\lfloor$$

$$= e^{-\alpha t}\left[1 - {}_{n-1}C_1\frac{\alpha}{p} + {}_{n-1}C_2\frac{\alpha^2}{p^2} + \ldots\ldots\right.$$

$$\left. + (-1)^r\,{}_{n-1}C_r\frac{\alpha^r}{p^r} + \ldots + (-1)^{n-1}\frac{\alpha^{n-1}}{p^{n-1}}\right] \rfloor\!\lfloor$$

$$\therefore v_n(t) = e^{-\alpha t}\sum_{r=0}^{n-1} {}_{n-1}C_r\,(-1)^r\frac{\alpha^r t^r}{r!} \qquad \ldots\ \ldots \quad (8)$$

Alternatively

$$v_n(p) \rfloor\!\lfloor = [1-h_1(p)]^n \rfloor\!\lfloor$$

$$= [1 - {}_nC_1 h_1(p) + {}_nC_2 h_2(p) + \ldots\ldots$$

$$+ (-1)^r\,{}_nC_r h_r(p) + \ldots\ldots + (-1)^n h_n(p)] \rfloor\!\lfloor$$

since $[h_1(p)]^r \rfloor\!\lfloor = \frac{\alpha^r}{(p+\alpha)^r} \rfloor\!\lfloor = h_r(p) \rfloor\!\lfloor$

$$\therefore v_n(t) = 1 + \sum_{r=0}^{n} {}_nC_r\,(-1)^r\,h_r(t) \qquad \ldots\ \ldots \quad (10)$$

APPENDIX 4

Response to a Unit Step of a Critically-damped Inductance-compensated Amplifier

The response to a unit step of the single-stage amplifier shown in Fig. 7 is $g_m R u_1(t)$ 1 where

$$\left.\begin{aligned} u_1(p) \rfloor\!\lfloor &= \frac{4\alpha^2+\alpha\beta}{(2\alpha+\beta)^2} \rfloor\!\lfloor \\ u_1(t) \rfloor\!\lfloor &= [1-e^{-2\alpha t}(1+\alpha t)] \rfloor\!\lfloor \end{aligned}\right\} \qquad \ldots\ \ldots \quad (12)$$

where $L = \frac{1}{4}CR^2$, $\alpha = 1/RC = R/4L$.

$$\therefore u_n(p) \rfloor\!\lfloor = \left[\frac{4\alpha^2+\alpha\beta}{(2\alpha+\beta)^2}\right]^n \rfloor\!\lfloor$$

Assume that $u_n(t) \rfloor\!\lfloor = \left[1-e^{-2\alpha t}\left(1 + {}_nb_1\frac{\alpha t}{1!} + \right.\right.$

$$\left.\left. {}_nb_2\frac{\alpha^2 t^2}{2!} + \ldots\ldots + {}_nb_{2n-1}\frac{\alpha^{2n-1}}{(2n-1)!}t^{2n-1}\right)\right] \rfloor\!\lfloor \quad (13)$$

If this is so,

$$u_{n+1}(t) \rfloor\!\lfloor = \frac{4\alpha^2+\alpha\beta}{(2\alpha+\beta)^2} \rfloor\!\lfloor -$$

$$\frac{4\alpha^2+\alpha\beta}{(2\alpha+\beta)^2}\cdot e^{-2\alpha t}\sum_{r=0}^{2n-1} {}_nb_r\frac{\alpha^r t^r}{r!} \rfloor\!\lfloor$$

But $f(p)\,e^{-\alpha t}\,g(t) \rfloor\!\lfloor = e^{-\alpha t}\,f(p-\alpha)\,g(t) \rfloor\!\lfloor$

$$\therefore u_{n+1}(t) \rfloor\!\lfloor = \frac{4\alpha^2+\alpha\beta}{(2\alpha+\beta)^2} \rfloor\!\lfloor -$$

$$e^{-2\alpha t}\cdot\frac{2\alpha^2+\alpha\beta}{\beta^2}\sum_{r=0}^{2n-1} {}_nb_r\frac{\alpha^r}{\beta^r} \rfloor\!\lfloor$$

$$= [1-e^{-2\alpha t}(1+\alpha t)] \rfloor\!\lfloor -$$

$$e^{-2\alpha t}\sum_{r=0}^{2n-1} {}_nb_r\left[2\frac{\alpha^{r+2}}{\beta^{r+2}} + \frac{\alpha^{r+1}}{\beta^{r+1}}\right] \rfloor\!\lfloor$$

$$= 1 - e^{-2\alpha t}\sum_{r=0}^{2n+1}[2\,{}_nb_{r-2} + {}_nb_{r-1}]\frac{\alpha^r}{\beta^r} \rfloor\!\lfloor$$

$$= \left[1 - e^{-2\alpha t}\sum_{r=0}^{2n+1} {}_{n+1}b_r\frac{\alpha^r t^r}{r!}\right] \rfloor\!\lfloor$$

where ${}_{n+1}b_0 = 1$ and ${}_{n+1}b_r = 2\,{}_nb_{r-2} + {}_nb_{r-1}$.

Therefore if equation (13) is valid for n stages, it is valid for $n+1$ stages, the coefficients having the above relationship. But the equation is valid for $n = 1$ (Equ. 12), so it is valid for any value of n. The coefficient ${}_nb_1 = 1$, therefore, ${}_2b_1 = 2$, ${}_2b_2 = 3$, ${}_3b_3 = 2$ and the coefficients for larger values of n can be similarly calculated.

APPENDIX 5

Response to a Unit Step of Resistance-coupled Amplifier with Many Stages

The response of the n-stage amplifier to a unit impulse (i.e., the limiting case of a pulse whose duration tends to zero, the product of its amplitude and duration being kept constant at unity[1]) is obtained by differentiating $h_n(t)$ and is given by

$$q_n(t) = \frac{(\alpha t)^{n-1}}{(n-1)!}e^{-\alpha t},\ t>0 \qquad \ldots\ \ldots \quad (15)$$

It can be shown that the mean value of αt for the curve of $q_n(\alpha t)$ is n and the standard deviation is $\sqrt{n}$.

$\therefore$ Putting $y = \frac{\alpha t - n}{\sqrt{n}}$

and transforming equation (15) in terms of the new variable,

$$q_n(y) = \frac{n^{n-1}\left(1+\frac{y}{\sqrt{n}}\right)^{n-1}e^{-\sqrt{n}y-n}}{(n-1)!}$$

since $\frac{dy}{d(\alpha t)} = \frac{1}{\sqrt{n}}$

If n is large, the factorial can be replaced by the Stirling approximation

$$n! = \sqrt{2\pi n}\, n^n e^{-n}$$

and $$\left(1 + \frac{y}{\sqrt{n}}\right)^n = e^A$$

where $$A = \log_e \left[1 + \frac{y}{\sqrt{n}}\right]^n$$

$$= n\left[\frac{y}{\sqrt{n}} - \frac{1}{2}\frac{y^2}{n} + \ldots\ldots\right]$$

Hence if $y^2 \ll n$,

$$g_n(y) \approx \frac{1}{\sqrt{2\pi}} e^{-y^2/2}$$

which is the expression for the normal or Gaussian law of distribution. Substituting for y,

$$g_n(t) \approx \frac{1}{\sqrt{2\pi n}} \exp\left[\frac{-(\alpha t - n)^2}{2n}\right] \quad \ldots \quad \ldots \quad (16)$$

We have shown that the shape of the response of a resistance-coupled amplifier to a very short pulse tends towards a Gaussian distribution curve as the number of stages is made very large. Equation (16) is only approximate for a finite number of stages and is inaccurate for small values of αt, moreover, it gives a value of $g_n(t)$ which is not zero for $t \leqslant 0$, which is physically impossible, but equation (16) represents $g_n(t)$ with increasing accuracy as the number of stages is increased.

The response of the amplifier to a unit step is

$$h_n(t) = \int_0^{\alpha t} g_n(\alpha t)\, d(\alpha t)$$

$$\therefore \quad h_n(y) = \int_{-\infty}^{y} g_n(y)dy = \int_{-\infty}^{0} g_n(y)dy + \int_0^{y} g_n(y)dy$$

But $$\int_{-\infty}^{0} \frac{1}{\sqrt{2\pi}} e^{-y^2/2}\, dy = \frac{1}{2}$$

and $$\frac{1}{\sqrt{2\pi}} \int_0^{y} e^{-y^2/2}\, dy = \frac{1}{2} \operatorname{erf}\left(\frac{y}{\sqrt{2}}\right)$$

$$\therefore \quad h_n(y) = \frac{1}{2}\left[1 + \operatorname{erf}\left(\frac{y}{\sqrt{2}}\right)\right]$$

Substituting for y,

$$\therefore \quad h_n(t) = \frac{1}{2}\left[1 + \operatorname{erf}\left(\frac{\alpha t - n}{\sqrt{2n}}\right)\right] \quad \ldots \quad \ldots \quad \ldots \quad (17)$$

This result has been given by Grant.[11] Tables of the error function can be found in text books on statistics[12, 13] and enable the response of resistance-coupled amplifiers to be calculated approximately when the number of stages is large.

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C.C.I.R. TELEVISION DELEGATION

Representatives of fifteen countries were in the delegation of the International Radio Consultative Committee which has been studying British television. Their visit was the last of a series, for they had previously been to France, Holland and the U.S.A. to see the systems used in those countries. Various demonstrations and visits to manufacturers were arranged and some of the outstanding items which they saw are briefly described below.

There was a demonstration of projection television on 20th April at the Odeon Cinema, Penge, by Cinema-Television Ltd., when the B.B.C. broadcast of the Cup Final was shown on a screen 20 ft by 15 ft. The projection tube was operated at 50 kV with an average beam current of 1·2 mA and a Schmidt optical system was used. The highlight brightness was stated to be 7 ft-lamberts.

A direct comparison between 405-line and 625-line television could be made in a closed-circuit demonstration at the E.M.I. works, the bandwidths used being respectively 3 Mc/s and 5·5 Mc/s. Two cameras were used side by side and the pictures appeared simultaneously on adjacent 15-in c.r. tubes. It was particularly interesting to observe that the improvement in picture definition with the greater number of lines was quite small. The importance of correct "gamma" and its effect on picture quality were also demonstrated.

In a visit to the Marconi Company at Great Baddow, cameras in the grounds and marquee produced pictures which were shown on sets in all parts of the building and the high sensitivity of the camera tubes was evident by the good pictures secured in the dusk. A large number of demonstrations of an instructive nature were also given and included one of "spot wobble" by Cinema Television.

At the B.B.C. research station 405-line and 625-line pictures were shown with a 3-Mc/s bandwidth and also with superimposed delay and echo distortions of known magnitude. It was shown that a 625-line picture was degraded by the limited bandwidth to a lower level than the 405-line and that it suffered much more severely from the distortions. A delay distortion of only 0·02 μsec, which it is hard to prevent in cable links, produced intolerable distortion of the 625-line picture, but permitted a usable 405-line picture to be obtained.

Demonstrations of the effect of thermal noise, and also of single-frequency interference, on a picture were given at the Post Office Research Station, Dollis Hill. A signal/thermal-noise ratio of about 30 db was shown to be necessary completely to avoid traces of thermal noise, but up to 60 db was needed in some cases for single-frequency interference. A television microwave-relay link was shown in operation and a method of measuring phase-delay on cables with a remote termination was shown and explained.

AMPLIFIER WITH NEGATIVE-RESISTANCE LOAD

Measurement of Stage Gain

By D. M. Tombs, M.Sc., A.M.I.E.E., and M. F. McKenna, B.Sc., A.C.G.I.

(Department of Electrical Engineering, Imperial College of Science and Technology, London)

SUMMARY.—The gain of a single-stage amplifier with a resistive load is always less than μ, the amplification factor of the valve. When a negative-resistance element is used as load, the gain can exceed μ and, theoretically, be made to increase indefinitely as the value of the negative-resistance approaches the differential anode resistance of the valve.

This paper describes experimental measurements of the stage gain up to 2.5 μ for a triode amplifier loaded with a negative-resistance element. An account is also given of the restrictions imposed on the operation of this type of amplifier by conditions of stability and the limitation of the gain due to the self-capacitance of the load.

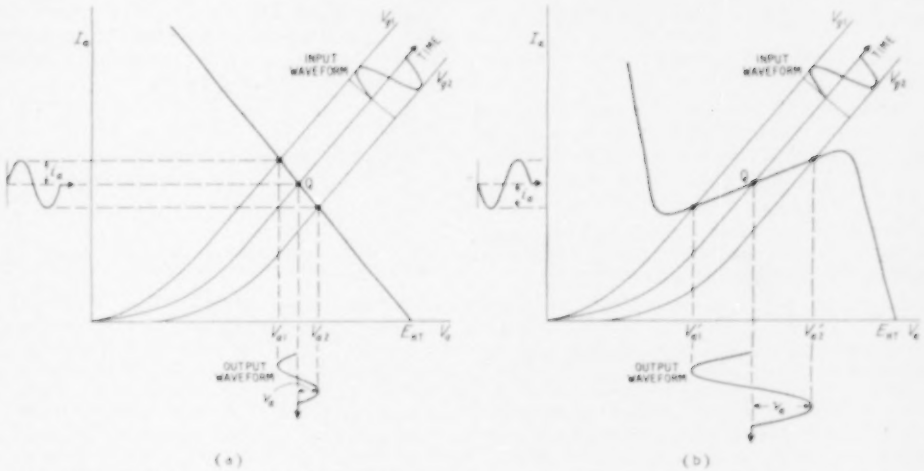
1. Introduction

FIG. 1(a) represents the load-line diagram of a triode valve amplifier having a load resistance R_L, with a quiescent or operating point at Q and a grid excursion between voltages V_{g1} and V_{g2}. E_{HT} is the battery supply voltage. The intercepts of the load line with the static characteristics give projections on the anode voltage (V_a) axis, at V_{a1} and V_{a2}. The voltage gain is given as $(V_{a2}-V_{a1})/(V_{g2}-V_{g1})$ and by inspection the output is in antiphase with the input. The maximum stage gain attainable is μ (i.e., when the load line is horizontal) and occurs when R_L becomes infinite. For triode amplifiers of this kind this is never achieved in practice because of the infinite steady voltage drop across the load resistance.

Voltage gains greater than μ can be obtained, however, by using a negative-resistor as load, the load line for this case is shown in Fig. 1 (b). For the same grid excursion, the projections of the intercepts on the V_a axis become V'_{a1} and V'_{a2} and consequently the voltage gain is the ratio $(V'_{a2}-V'_{a1})/(V_{g2}-V_{g1})$, a value which approaches infinity as the load line becomes tangential to the valve characteristic at the point Q; i.e., when the magnitude of the negative-resistance approaches the differential anode resistance of the valve. By inspection the output is again in antiphase with the input, although the anode current has changed phase by 180°.

An alternative method of achieving the same

MS accepted by the Editor, December 1949.



(a) (b)

Fig. 1. *Load-line diagrams (a) with positive- and (b) with negative-resistance load. The anode currents are in opposite phase.*

result, as suggested by Dowling[1], is to operate a tetrode valve on the negative slope of its I_a/V_a characteristic in conjunction with a resistive load. If the magnitude of the load resistance is adjusted to a value less than, but approaching, the differential anode reristance of the valve at its operating point, gains greater than μ are attainable.

The object of this paper is to confirm, by experiment, that stage gains greater than μ can be obtained with a triode valve amplifier when a negative resistance is used as load, and that the circuit is stable.

2. Theory

2.1. *Gain of Single-stage Amplifier.*

The expression for the voltage amplification of a single-stage amplifier is

$$A = -\frac{\mu Z}{r_a + Z} = -\frac{\mu}{1 + r_a/Z} \qquad (1)$$

where Z is the impedance of the anode circuit, and r_a is the differential anode resistance of the valve.

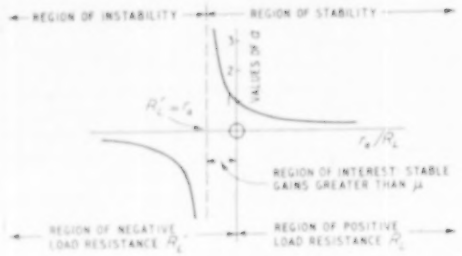

REGION OF INSTABILITY
REGION OF STABILITY
VALUES OF a
$R_L' = r_a$
r_a/R_L
REGION OF INTEREST: STABLE GAINS GREATER THAN μ
REGION OF NEGATIVE LOAD RESISTANCE R_L'
REGION OF POSITIVE LOAD RESISTANCE R_L

Fig. 2. *Relation of normalized amplification a to r_a/R_L.*

Introducing a new symbol a, the normalized amplification and defining it as $a = A/(-\mu)$ equation (1) may be expressed in the form

$$a = \frac{1}{1 + r_a/Z} \qquad (2)$$

For increasing values of anode load impedance, a tends to unity, and when the anode load becomes resistive (i.e., for $Z = R_L$)

$$a = \frac{1}{1 + r_a/R_L} \qquad (3)$$

The curve of a as a function of r_a/R_L is plotted to the right of the origin in Fig. 2.

2.2. *Single Stage with Negative-resistance Load*

If, however, R_L is made negative, say $-R_L'$, then

$$a = \frac{1}{1 + r_a/(-R_L')} = \frac{1}{1 - r_a/R_L'} \qquad (4)$$

and evidently a can have values greater than unity tending to infinity as R_L' tends to r_a. The effect of varying the value of R_L' is shown to the left of the origin in Fig. 2.

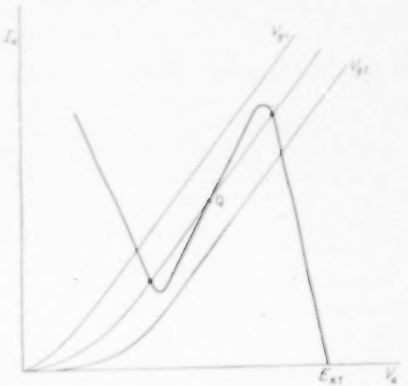


Fig. 3. *Triple intersection.*

2.3. *Stability.*

Now R_L' can approach r_a in two ways, from a larger value than r_a or from a smaller. Which of the two, if either, is stable can be readily determined from consideration of Fig. 1(a) and (b). Referring to Fig. 1(a), for any given grid potential there is a single point of intersection between the valve characteristic and the load line. This is the single-valued solution of the Kirchhoff equation for the anode mesh

$$E_{HT} + V_a + V_L = 0 \qquad (5)$$

where V_a is a non-linear function of I_a given by the curve, and V_L is a linear function of I_a given by the load line; viz., $V_L = I_a R_L$.

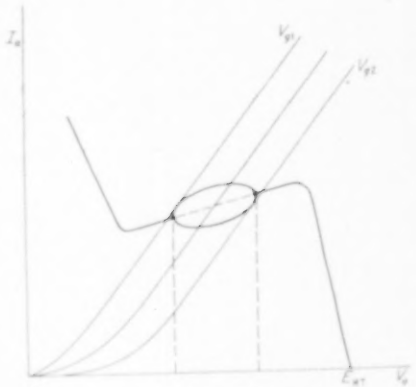


Fig. 4. *Elliptical excursion.*

In Fig. 1(b) the intersection of the load line and the characteristic for a given grid potential is seen to be single valued and the circuit is stable. This condition arises when $R_L' > r_a$. When, however, the load line is seen to have multiple intercepts with the characteristic as in Fig. 3, the amplifier is unstable, a condition for which $R_L' < r_a$.[2,3] These conditions apply only to voltage-controlled negative resistors; the reverse is true for the current-controlled types.

2.4. *Effect of Shunt Capacitance.*

The inevitable presence of the shunt capacitance of the load means that equation (2) may be wrttten

$$a = \frac{1}{1 + r_a/R_L + j\omega C r_a} \quad .. \quad .. \quad (6)$$

where C is the load self-capacitance, $\omega = 2\pi f$ and f the frequency of the applied signal, and equation (4) as

$$a = \frac{1}{1 - r_a/R_L' + j\omega C r_a} \quad .. \quad .. \quad (7)$$

For stability under static control conditions R_L' must be greater than r_a, and within this limitation, the magnitude of a cannot be greater than $1/\omega C r_a$. For this case the excursion on the load-line diagram becomes elliptic and is shown qualitatively in Fig. 4. The expression for a in equation (6) may be plotted on a vector diagram giving a locus for variations of r_a/R_L and r_a/R_L'. This is shown in Fig. 5(a) and (b) on the assumption that f, C, and r_a are constant. It will be seen from Fig. 5(b) that the locus of a is a semi-circle of diameter $1/\omega C r_a$, which is the maximum value a can have under the assumed conditions.

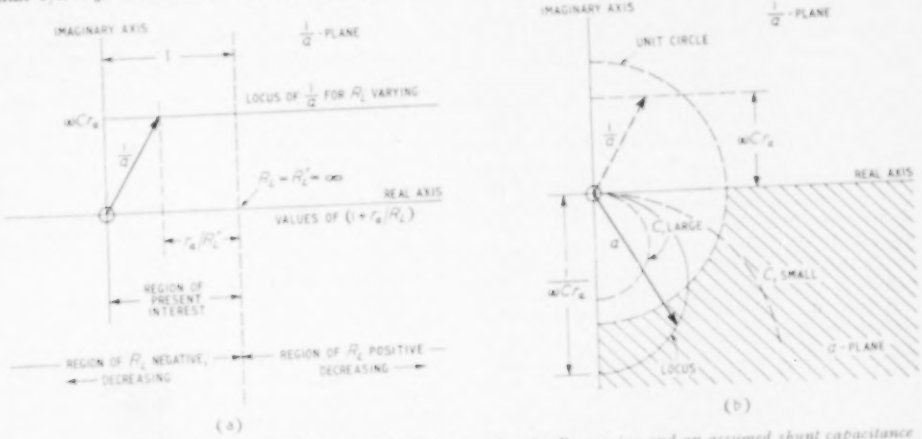


Fig. 5. *(a) and (b) show respectively the vector loci of 1/a and a, for R_L varying and an assumed shunt capacitance C, (stage gain is proportional to a). The shaded region in (b) shows the area in which gains greater than μ occur.*

3. Experimental

3.1. *Negative-Resistance Elements.*

Two forms of voltage-controlled negative resistors were considered:

(a) A tetrode valve operating on the negative slope of its I_a/V_a characteristic.

(b) A cathode-coupled negative-resistance circuit.

The first of these was used initially, but was later replaced by (b). The circuit diagram of this device, together with the current-voltage characteristic at its input terminals AB, are shown in Fig. 6(a) and (b) respectively.*

In order to obtain the requisite variation of resistance, a calibrated resistance R was connected across AB, the combination providing positive or negative values according to the relative magnitudes of R and the negative input-resistance of the device:

viz., $R_L' = -\dfrac{R R_n}{R - R_n}$ ohms, for R greater than R_n

or $R_L = \dfrac{R R_n}{R - R_n}$ ohms, for R_n greater than R

where R_n is the magnitude of the negative input-resistance.

The apparatus used for the experiment on the stage gain is shown in Fig. 7. The negative-resistance element was isolated from the d.c. circuit of the amplifier by a 1.0-μF capacitor. As R was changed to afford the desired variation of R_L and R_L', the h.t. supply voltage was also changed so as to ensure operation about

* For a full discussion of the behaviour of the circuit, see reference 4.

the same point on the valve characteristic.

The grid circuit comprised a d.c. potential divider for biasing the amplifying valve to the desired operating point and a calibrated attenuator permitted the adjustment of the 1,000-c/s input signal.

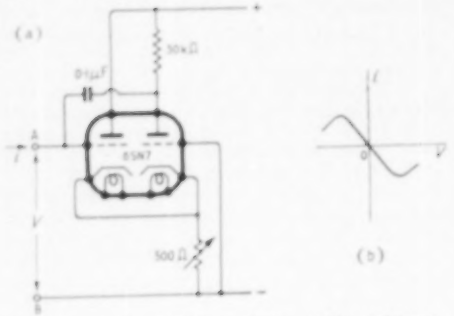


Fig. 6. *(a) Cathode-coupled negative-resistance circuit and (b) static i/V characteristic at input terminals A and B.*

3.2. *Measurements.*

The constants μ and r_a of the amplifying valve at the quiescent point were obtained from measurements on a Miller Bridge[8] and were found to be, respectively, 14.99 and 8776 ohms.

The technique employed for the measurement of stage gain consisted of adjusting, to a constant value on an oscilloscope, the input voltage to the valve so as to make the amplitude of the output voltage equal to that across the supply points (a) and (b) of the attenuator. The gain of the stage expressed in decibels was then read directly from the scale of the attenuator.

The load resistance was measured on an audio-frequency bridge operated on the same frequency as that of the signal applied to the amplifier; viz., 1,000 c/s. To facilitate measurements of positive and negative values of load resistance

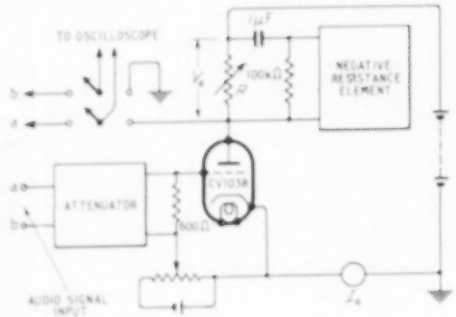


Fig. 7. *Diagram of measuring equipment.*

on the same bridge, a known resistance of 1,851 ohms was placed in shunt with the load to give a combination whose resistance value remained positive. The load had a shunt self-capacitance of the order of 0.002 μF, the susceptance of which, at the operating frequency, was comparable with the conductance of the load over the range of R_L' and was included in the calculations of the performance of the amplifier.

3.3. *Experimental Results.*

Detailed experimental results are given in tabular form in the Appendix and the experimental curve relating a and r_a/R_L is shown, alongside the theoretical one, in Fig. 8.

For values of gain above 2.5μ the output waveform became noticeably distorted and prevented reliable results from being obtained. Smaller input signals were used in an attempt to overcome this, but the pick-up voltages in the grid circuit were sufficient to make the results inaccurate.

The effect of the shunt self-capacitance of the load could be neglected for values of r_a/R_L greater than 2, but for smaller values, and for values of

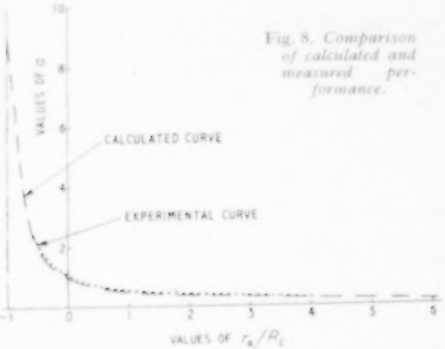


Fig. 8. *Comparison of calculated and measured performance.*

r_a/R_L' less than unity it had to be taken into account. The limit of a for $r_a/R_L' = 1$ was determined by the self-capacitance of the load, as previously indicated, and was approximately 9.

4. Conclusions

The object of this paper was to confirm experimentally that stage gains in excess of μ could be obtained with a triode amplifier using a negative-resistance load. The experimental and theoretical results agree within 6% for gain of 2.5μ with a closer agreement for smaller values. The occurrence of distortion prevented the determination of higher values of gain, but even in the absence of distortion the self-capacitance of the load would have limited the gain to approximately 9μ.

The restrictions imposed on the amplifier for stable operation, necessitated the magnitude of R_L' being greater than r_a and if higher gains are required, the input must diminish if distortionless output is to be maintained.

Acknowledgments

The authors wish to express their thanks to Prof. Willis Jackson and Dr. J. Lamb for suggestions made when reading the manuscript of the paper and also to A. C. Nicolls for the help given with the experimental work.

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APPENDIX

Values of Stage gain (db)	Values R_a (Ω)	Values of R_L (Ω)	Values of r_a/R_L	Calculated values of a	Exptl. values of a
6.0	2142	1,440	6.1	0.143	0.133
9.0	2142	1,878	4.67	0.176	0.187
13.5	2150	4,010	2.185	0.310	0.315
16.5	2155	6,210	1.412	0.415	0.445
19.0	2155	10,920	8.803	0.552	0.594
22.0	2146	29,420	0.298	0.769	0.839
23.5	2145	100,200	0.088	0.917	0.996
24.0	2142	− 576,000	− .015	1.01	1.055
25.0	2140	− 78,500	− .112	1.12	1.186
26.0	2145	− 46,000	− .191	1.22	1.330
27.0	2120	− 27,100	− .325	1.46	1.491
28.0	2120	− 21,670	− .405	1.65	1.672
29.5	2120	− 18,200	− .482	1.87	1.990
30.0	2120	− 17,100	− .514	2.00	2.105
31.0	2120	− 15,710	− .560	2.20	2.360

NEW BOOKS

Leitfaden der Elektrotechnik. Vol. I. Grundlagen der Elektrotechnik.

By Moeller and Wolff. Pp. 358 + x. With 257 illustrations. B. G. Teubner Verlagsgesellschaft, Leipzig.

This is the fourth edition of this textbook on the fundamentals of electrical engineering. The authors are professors at Brunswick and Nuremberg respectively. The foundations of the subject are laid with great care and thoroughness; the mathematical treatment is very clear, and diagrams are used wherever they can be of any help. In the earlier editions coloured diagrams were used, but this is not possible under present conditions. An interesting innovation is the numbering of the illustrations by the page on which they appear, thus a diagram on p. 129 in Fig 129.1; this makes it very easy to find any given figure, but it is difficult to see why the .1 need be added when there is only one figure on the page, as is nearly always the case. Many of the vector diagrams would look much neater if the Gothic type were replaced by Roman type. As an example of the detailed information given, there is a table on p. 19 giving not only the resistivities and conductivities of the various metals and alloys, but also both α and β in the formula $R_2 = R_1[1 + \alpha(\theta_2 - \theta_1) + \beta(\theta_2 - \theta_1)^2]$ in which the initial temperature θ_1 is taken as 20°C. In another column is also given the value of τ (235 for copper) which, if added to the Centigrade temperature, gives an 'absolute' temperature to which, over the ordinary working range, the resistance is proportional.

The subjects dealt with cover electric circuits, energy and power, thermo-electricity, electrolytes and cells, magnetic and electric fields, alternating currents including locus diagrams and resonance, choking coils and air-core transformers, waveforms, and the measurement of three-phase power. A new chapter has been inserted on the calculation of single-phase and three-phase transmission lines, but unfortunately the index was not corrected and the references to subsequent items are all eight pages wrong; thus 'Schaltzeichen' is not on p. 342, as stated, but on p. 350.

The magnetic field is developed on modern lines; the unit pole is not mentioned, and the magnetic-field strength H is introduced as another name and symbol for the ampere-turns per cm.

The system of units employed is called the practical system, but it is not the m.k.s. system, and the name of Giorgi is not mentioned. The centimetre is maintained as the unit of length. The units of B, H, $\mathfrak{E}$ and D are 1 V sec/cm², 1 A/cm, 1 V/cm and 1 C/cm² respectively, but the gauss and maxwell are also employed. The rationalized system is used and the permeability of space is given as

$$\mu_0 = 1.256 \times 10^{-8}\ \text{H/cm} = 1.256 \times 10^{-8}\ \text{V sec/A cm}$$
$$= 1.256\ \text{G cm/A} = 1.256\ \text{M/A cm}$$

where G and M stand for gauss and maxwell.

An outstanding feature of the book is the great number of numerical examples which are worked out in detail.

This is a textbook that can be unreservedly recommended to either student or teacher with a knowledge of German.

G. W. O. H.

Electronic Valves

Book II, Data and Circuits of Receiver and Amplifier Valves. Pp. 409 + xii. Price 21s.

Book III, Data and Circuits of Modern Receiver and Amplifier Valves (1st Supplement). Pp. 213 + x. Price 12s. 6d.

Book IV, Application of the Electronic Valve in Radio Receivers and Amplifiers. Pp. 416 + xxiv with 256 illustrations. Price 35s.

Cleaver-Hume Press Ltd., 42a, South Audley St., London, W.1.

The first book of this series, "Fundamentals of Radio Valve Technique," was reviewed in *Wireless Engineer* for December 1949, p. 413. The series has the general title "Electronic Valves," and is published by N. V. Philips, Gloeilampenfabrieken, Eindhoven, Holland.

Books II and III chiefly comprise details of the characteristics of Philips' valves. In the former nearly three-quarters of the book is devoted to this and most of the rest to examples of typical apparatus embodying the valves. Circuit diagrams with values of components

and general technical descriptions are given. The valves included are mainly the E, C and K series. Book III is similar but covers the more recent E20, U20, D20 and U series of Philips' Valves.

Book IV is in the nature of a wireless-receiver text book and is of general application. It covers the receiver from the aerial input to the detector; a.f. amplification is to be treated in Book V which has not yet appeared. Many matters, too, which some may consider should have been included in Book IV, such as noise, are not treated here but are to be covered in a future Book VI.

Book IV opens with a general discussion of the single-tuned circuit and then goes on to deal with the properties of coupled circuits. Amplification is then treated, first at radio and then at intermediate frequency and included in this section is a detailed account of aerial-coupling methods.

The frequency-changer follows and, as part of it, the oscillator is treated in great detail. A very detailed analysis is given of the operation of a squegging oscillator. It forms one of the best published accounts of this and includes a method of predicting whether or not a given oscillator will squeg.

The determination of circuit values for superheterodyne tracking is covered and cross modulation and modulation distortion are very fully treated. There is also a section on superheterodyne whistles. The detector is well explained and the effect of the ratio of the a.c. to d.c. loads of a diode is covered, not only as regards distortion but as regards the effect on the selectivity of the preceding tuned circuit and the modulation depth of the signal developed across it. It is too often overlooked in text books that a low ratio of a.c./d.c. loads so affects the input tuned circuit that the modulation depth of the signal developed across it is reduced and that, in its turn, this reduces the amount of distortion introduced in the detector itself by the low ratio of the loads. This is far from new, of course, but it is not always recognized and it is refreshing to find it fully treated. It is shown in one example that in a particular case the effect results in the critical modulation depth (for the appearance of distortion) of the incoming signal being 81% instead of 66% only.

The treatment throughout is very thorough but it is done almost entirely from the viewpoint of the designer of broadcast receivers. Most emphasis is given to medium- and long-waveband problems and short-wave matters are discussed chiefly from the point of view of the designer who wants to include a single s.w. band of wide coverage in what is primarily a medium- and long-wave set.

There is a good deal of mathematics in the book, although not of a very highbrow nature. The choice of symbols is sometimes strange to British eyes and the elaborate subscripts employed sometimes make the equations unnecessarily difficult to follow. The language too, might be improved. The book is a translation and, although it is a good one, the reader cannot be but aware of it.

W. T. C.

Telecommunications and Equipment in Germany during the period 1939-1945.

British Intelligence Objectives Sub-committee Surveys, Report No. 29. Pp. 55. H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 1s. 6d.

This is a survey of a large number of B.I.O.S., C.I.O.S., F.I.A.T. and J.I.O.A. reports which are listed individually as a bibliography. It is concerned mainly with line telephony and telegraphy, but there are a few pages devoted to research (mainly on materials) and about six pages to radio, including broadcasting, wire broadcasting and television.

The Williamson Amplifier

By D. T. N. Williamson. Pp. 28 + vi with 31 illustrations. Iliffe & Sons Ltd., Dorset House, Stamford St., London, S.E.1. Price 3s. 6d. (postage 2d.).

A collection of articles on a high-quality amplifier reprinted from *Wireless World*.

CORRESPONDENCE

Differential Amplifiers

Sir,—In the April issue Dr. D. H. Parnum introduces the term 'transmission factor' as an overall measure of performance for differential amplifiers fed at the input with a high ratio of in-phase interference/anti-phase signal. Perhaps 'differential transmission factor' is a better term, and one not in conflict with other types of communication circuits?

There is still a place for 'discrimination ratio' as a design factor, for it represents the calculable degenerative discrimination assuming perfect balance. The several imperfections in balance cannot be predicted with any certainty, but they can be compensated for individually as Dr. Parnum has shown, and this possibility was pointed out in the passage from my article* which he has quoted.

The commercial amplifier I described was designed for the use of medical technicians, with a 'factor of safety,' or margin of performance, in order that the number of adjustments be kept to a minimum. This was done by employing degenerative circuits in preference to balanced circuits throughout. The literature on sensitive and d.c. amplifiers contains very many interesting and ingenious balancing circuits, but few have found any permanent place in electronic engineering because they have been called upon to work at the limit of their performance.

Dr. Parnum assumes that the tolerances of unbalance will be additive, and predicts a 'differential transmission factor' of 400, where I found the measured value in my Fig. 10(a) to be at least 3,000. I think this is because the single zero-adjusting resistance does, in fact, tend to equalize the amplification factors of the two valves as well. In the passage he quotes I should have referred to an 'effective' discrimination factor of 100,000, but I now prefer the new term discussed above.

Denis L. Johnston.

Aldenham, Hertfordshire.

* *Wireless Engineer*, Aug., Sept., Oct. 1947.

SYMPOSIUM ON INFORMATION THEORY

A symposium on Information Theory is to be held in the rooms of the Royal Society from September 26th–29th inclusive. The programme will discuss, in particular, the recent work of Dr. C. Shannon of the Bell Telephone Laboratories, N.J., who will himself present two papers, and it will be of interest to mathematicians, physicists, physiologists and communication engineers. Those wishing to attend are asked to write to Prof. Willis Jackson, Electrical Engineering Dept., Imperial College, London, S.W.7.

CORRECTION

An error occurred in the caption to Fig. 6 in the paper "Secondary Emission Valve" by G. Diemer and J. L. H. Jonker in the May issue, p. 137. The dotted-line curves are both for the secondary-emission triode under discussion and the solid-line for a different valve with greater spacing between the anode and the secondary emitter.

ABSTRACTS and REFERENCES

Compiled by the Radio Research Board and published by arrangement with the Department of Scientific and Industrial Research

The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of the titles of journals are taken from the World List of Scientific Periodicals. Titles that do not appear in this List are abbreviated in a style conforming to it.

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ACOUSTICS AND AUDIO FREQUENCIES

534+621.395.62 **1319**

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

14. Representations of Speech Sounds and some of their Statistical Properties.—Sze-Hou Chang, G. E. Pihl & M. W. Essigmann.
127. Sound-System Design for Reverberant Auditoriums.—L. L. Beranek, W. H. Radford & J. B. Wiesner.
128. High-Efficiency Loudspeakers for Personal Radio Receivers.—H. F. Olson, J. C. Bleazey, J. Preston & R. A. Hackley.
129. A Review of Direct Radiator Loudspeakers.—F. H. Slaymaker.
130. Loudspeaker Housings.—W. F. Meeker.
131. A Miniature Condenser-Type Microphone.—J. K. Hilliard.
148. Noise Considerations in Audio Systems.—F. L. Hopper.
149. Considerations of Noise in Sound Recording and Reproducing Systems.—A. W. Friend.
150. Magnetic Recording Frequency Response—Measurement Procedures and Pitfalls.—R. E. Zenner.
151. Distortions in Recording Systems.—H. E. Roys.
152. Perceptibility of Flutter in Recorded Speech and Music.—H. Schecter.

534.231 **1320**

On the Energy Flux in the Fields of Spherical Sound Radiators.—S. N. Rzhevkin. (*Zh. tekh. Fiz.*, Dec. 1949, Vol. 19, No. 12, pp. 1389–1396. In Russian.) Using Bessel and Neumann spherical functions, a generalized expression is derived determining the sound field of a complex spherical radiator. A relation is established between the Stokes-Rayleigh functions $f(jkr)$ and $F(jkr)$ normally used and the more convenient new functions $G(kr)$, $D(kr)$, $\epsilon(kr)$ and $\delta(kr)$. Tangential energy fluxes are absent in the fields of simple radiators but are always present in the fields of complex radiators. As an example, the radiator with two modes of oscillation is discussed in detail. Zonal and sectoral radiators are also considered.

534.231 : 534.26 **1321**

On the Freely Vibrating Circular Disk and the Diffraction by Circular Disks and Apertures.—C. J. Bouwkamp. (*Physica, 's Grav.*, Jan. 1950, Vol. 16, No. 1, pp. 1–16. In English.) A theory is developed for the acoustic field produced by a freely vibrating rigid disk when the wavelength is large compared with the radius a of the disk. By analysis based on integral equations, an expression for the field is derived in the form of a series of ascending powers of ka, where k is the wave number. The results are equally applicable to the diffraction of plane scalar waves incident normally upon a circular disk or aperture.

534.232+534.39 **1322**

Powerful Acoustic Waves.—P. Alexander. (*Research, Lond.*, Feb. 1950, Vol. 3, No. 2, pp. 68–73.) Discussion of various methods of producing high-power ultrasonic oscillations, and of the chemical and physical effects produced by such oscillations in solids and liquids. The many diverse phenomena occasioned by ultrasonic irradiation are ascribed either to cavitation or to the enormous acceleration of particles in the sound field.

534.321.9 **1323**

Ultrasonic Vibrations.—E. Skudrzyk. (*Elektrotech. u. Maschinenb.*, March 1950, Vol. 67, No. 3, pp. 76–84.) Discussion of the production and effects of ultrasonic vibrations in gases, liquids and solids, the conditions being fundamentally different in the three cases.

534.321.9 : 534.373 **1324**

Ultrasonic Reverberation Measurements in Liquids: Part 2.—C. E. Mulders. (*Appl. sci. Res.*, 1950, Vol. B1, No. 5, pp. 341–357.) Measurements of the absorption of ultrasonic waves in various solutions suggest that the high absorption in sea water may be due to perturbation of the reaction $MgSO_4 \rightleftharpoons Mg + SO_4$ and is not associated with NaCl, as has been suggested by Liebermann (613 of 1949). Part 1: 932 of 1949.

534.6 : 621.395.632.11 **1325**

Acoustical Study of Telephone Bells of the French P.T.T. Administration.—(*Ann. Télécommun.*, Jan. 1950, Vol. 5, No. 1, pp. 21–28.) Description of the apparatus and methods used to study telephone ringing, with a view to establishing new standards for intensity and spectral composition of the sound emitted.

534.62 **1326**

Room for Acoustic Tests of Loudspeakers and Microphones.—M. Milosevic. (*Rev. tech. Comp. franç. Thomson-Houston*, Feb. 1950, No. 13, pp. 33–42.) The room

is constructed according to principles discussed in 1699 of 1949. Overall dimensions are: length 5.5 m, width 2.7 m, height 3 m. The test chamber, about 3 m long, is paraboloidal at the end which houses the loudspeaker and opens out to cylindrical shape. The walls of the chamber are thickly lined with glass wool. Test results are shown in many diagrams. Measurements in the test chamber on loudspeakers and microphones give results in good agreement with free-field measurements.

534.771 1327

The Development of Hearing-Test Methods.—W. Beindorf. (*Funk u. Ton*, Feb. 1950, Vol. 4, No. 2, pp. 76–84.)

534.78 : 621.395.822 : 629.13 1328

Telephony and the Problem of Noise in Aircraft.—P. Chavasse & R. Lehmann. (*Ann. Télécommun.*, Feb. 1948, Vol. 3, No. 2, pp. 45–56.) Discussion of the noise level and noise spectra in different types of aircraft and their combined effect in masking speech sounds.

534.784 1329

The Reproduction of Natural Speech Sounds.—H. Koschel. (*Fernmeldetech. Z.*, Feb. 1950, Vol. 3, No. 2, pp. 48–53.) A review of methods of producing artificial speech sounds for technical purposes.

534.782.07 1330

The Phonetic Steno-Sonograph.—J. Dreyfus-Graf. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st March 1950, Vol. 28, No. 3, pp. 89–95. In French, with German summary.) Electroacoustic apparatus which records the spoken word in written characters, examples of which are shown.

534.84 1331

The Intelligibility Ratio as the Criterion of the Acoustic Quality of a Hall.—A. Moles. (*Ann. Télécommun.*, Feb. 1950, Vol. 5, No. 2, pp. 57–64.) Reverberation time and sound distribution are insufficient to determine precisely the acoustic quality of a hall. A better criterion is provided by measurements of the intelligibility of articulated sounds at different points in the hall. Based on an analysis of the occurrence of different sounds in speech, two lists are compiled of 100 French logatoms, each consisting of two consonants and a vowel, suitable for use in such measurements.

534.862.4 1332

Direct Methods of Frequency Linearization of the Output from the Reproducing-Head Circuit.—F. Grammelsdorff & W. Guckenburg. (*Funk u. Ton*, Feb. 1950, Vol. 4, No. 2, pp. 66–75.) The effects of introducing resistance, capacitance and inductance in the reproducing-head circuit on the shape of the response curve are examined and shown in diagrams. With a suitable combination the output voltage can be kept nearly constant at about 3 mV from 40 c/s to 50 kc/s. With better design of the equipment, the output voltage can be raised to about 10 mV. Any further increase depends on improvement of the magnetic properties of the tape used.

621.3.012 : 621.317.089 1333

A Modern Electroacoustic Frequency-Response Recording Unit.—Lehner. (*See* 1449.)

621.395.625.2 1334

Disc-Recording Standards.—B. E. G. Mittell. (*Proc. Instn Radio Engrs, Aust.*, Jan. 1950, Vol. 11, No. 1, pp. 5–14.) 1948 Australian I.R.E. Convention paper reviewing the development of standards for commercial disk recording. Present standards and methods of testing used in the laboratories of Electric and Musical Industries Ltd, Hayes, Middlesex, are discussed. A comprehensive table is given of current practice and recommended standards. See also 1243 of 1948.

621.395.92 1335

Crystal Earpieces for Portable Hearing-Aids.—W. Güttner. (*Z. angew. Phys.*, Jan. 1950, Vol. 2, No. 1, pp. 33–39.) The construction is described of an earpiece in which a double crystal plate of Rochelle salt is coupled to a Helmholtz resonator. From the equivalent electrical circuit the sound pressure produced in the earpiece may be simply calculated. The characteristics of two such earpieces are plotted. The range of coupling, tuning and damping of the crystal and resonator combination is relatively narrow for linearity of the response curve.

621.396.645.37 : 621.395.623.7 : 621.3.018.8 1336

Output Impedance Control.—D. W. Thomasson. (*Wireless World*, March 1950, Vol. 56, No. 3, pp. 116–117.) Comment on 1070 of May (Roddam).

621.396.645.37 : 621.395.623.7 : 621.3.018.8 1337

Output Impedance Control.—T. Roddam: P. J. Baxandall: H. Pursey: E. Jeffery: H. J. Pichal. (*Wireless World*, April 1950, Vol. 56, No. 4, pp. 155–157.) Author's reply to 1336 above, and further comment on 1070 of May.

AERIALS AND TRANSMISSION LINES

621.392.26* + 621.396.67 1338

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

32. Waveguide Applications of Artificial Metallic Dielectrics.—W. E. Kock.
33. The Effects of Anisotropy in a Three-Dimensional Array of Conducting Disks.—G. Estrin.
34. A Study of Single-Surface Corrugated Guides.—W. Rotman.
35. A Study of the Current Distribution on the Helix.—J. A. Marsh.
36. Diffracted Beams in Metal Lenses.—A. E. Heins.
57. On the Relation between the Geometry and the Impedance Characteristics of Typical Radiating Systems.—T. H. Crowley & V. H. Rumsey.
58. A Method for Studying the Response of Loops to the Electromagnetic Field.—B. C. Dunn, Jr.
59. Measurement of the Radiation Efficiency of Elliptically and Linearly Polarized Antennas.—J. Rowen.
60. Broad-Band Unidirectional Antenna 50 to 170 Mc/s.—V. J. Colaguori & R. Guenther.
61. Antenna System for Very-High-Frequency Radio Ranges and Direction Finding.—F. J. Lundburg & F. X. Bucher.
73. Radiation from Circular Current Sheets.—W. R. LePage, C. S. Roys & S. Seely.
74. Radiation Patterns of Circular and Cylindrical Arrays.—J. E. Walsh.
75. Properties of Guided Waves on Inhomogeneous Cylindrical Structures.—R. Adler.
79. A Supergain U.H.F. Television Transmitting Antenna.—O. O. Fiet.
122. Surface-Wave-Transmission Lines.—G. Goubau.
123. Frequency-Modulation Distortion in Linear Systems having Small Sinusoidal Irregularities in Transfer Characteristics, with Application to Lossless Waveguides.—F. Assadourian.
124. The Representation, Measurement, and Calculation of Equivalent Circuits for Slots in Rectangular Waveguide.—J. Blass, L. Felsen, H. Kurss, N. Marcuvitz & A. A. Oliner.
125. Dielectric Tube Antennas.—R. E. Beam & D. G. Harman.
126. Measurement of Current and Charge Distributions on Antennas and Open-Wire Lines.—D. J. Angelakos.

621.392.43 **1339**

Two-Band Antenna-Matching Networks.—J. G. Marshall. (*QST*, Feb. 1950, Vol. 34, No. 2, pp. 36–39, 90.) Continuation of 34 of January. To demonstrate the use of the design formulae previously given, numerical examples are calculated for a simple aerial operating on its fundamental and second-harmonic frequencies, using different types of transmission line.

621.396.67 : 621.315.625.015 **1340**

Investigation of the Voltages on Insulators in the Guy Wires of Tower Aerials.—A. A. Metrikin. (*Radiotekhnika, Moscow*, Nov./Dec. 1949, Vol. 4, No. 6, pp. 59–62. In Russian.)

621.396.671 **1341**

The Transmission and Reception of Elliptically Polarized Waves.—G. Sinclair. (*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 148–151.) A vector parameter is defined which represents a generalization of the effective length of an aerial to include a specification of the polarization of the field radiated by the aerial. The parameter so defined is also useful in calculating the voltage at the terminals of the aerial when it is used to receive plane waves of arbitrary (elliptical) polarization.

621.396.677 **1342**

Triplet Reflector Array.—R. W. Hogg. (*Wireless Engr*, Feb. 1950, Vol. 27, No. 317, pp. 47–53.) The basic system described consists of a horizontal dipole with a reflector system in which the usual single parasitic element is replaced by three elements spaced vertically $\lambda/8$ apart; arrays of one and two such units are considered. From theoretical considerations this design was expected to give not only an improved back-to-front ratio, but also, due to its decreased sensitivity to frequency variation, a bandwidth over twice that for the single reflector system. The improvement observed in practice fell short of that predicted theoretically, the bandwidth for a wavelength of 6 m increasing from 2 Mc/s for a 2-stack single-reflector array to 3 Mc/s for the corresponding triplet array.

621.396.677 **1343**

Calculations for [parabolic] **Reflectors.**—R. Brendel. (*Funk u. Ton*, Feb. 1950, Vol. 4, No. 2, pp. 93–99.) A general formula is derived for the gain of a parabolic reflector, and the direct radiation and the reaction of the reflector on the transmitting dipole are discussed. The field distribution is calculated for parabolic and cylindro-parabolic reflectors of various apertures and the resulting curves are compared with Köhler's results for sheet-metal and grid-type reflectors (1932 Abstracts, p. 525). The radiation characteristics are determined for a paraboloic reflector without assuming a uniform intensity distribution over the surface of the reflector.

621.396.677 **1344**

An Experimental Verification of the Theory of Parallel-Plate Media.—C. A. Cochrane. (*Proc. Instn elect. Engrs*, Part III, March 1950, Vol. 97, No. 46, pp. 72–76.) The transmission coefficient and deviation for various angles of incidence of a plane wave on a parallel-plate prism were measured. The results obtained are compared with values calculated from an idealized theory in which plate thickness and resistivity are neglected and an infinite number of plates is assumed. This theory explains qualitatively the action of the prism, but the plate thickness must be taken into account to obtain quantitative agreement with experimental results.

621.396.677 **1345**

Wide-Angle Metal-Plate Optics.—J. Ruze. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 53–59.) 1949 I.R.E. National Convention paper. A description of microwave metal-plate lenses of the 'constrained' type, in which focusing takes place normal to the electric vector. These are shown to have exceptional wide-angle scanning properties. General design formulae and expressions for phase aberration and the effect of refocusing are derived. Particular designs are investigated and their properties tabulated, together with a graph giving maximum scanning angle as a function of bandwidth for each type. A wide-angle 2-medium lens is also discussed.

621.396.67 **1346**

The A.R.R.L. Antenna Book. [Book Review]—Publishers: American Radio Relay League, West Hartford, Conn., 1949, 265 pp., $1.00. (*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, p. 191.) "Amateurs, experimenters, and practical radio men will find this book replete with useful information on antennas intended chiefly for amateur applications. The book is a thoroughly revised version of the previous edition."

CIRCUITS AND CIRCUIT ELEMENTS

621.3.07 + 621.396.645.37 **1347**

Control, Positive and Negative Feedback and Negative Resistance Coordinated.—W. Reichardt. (*Elektrotechnik, Berlin*, Feb. & March 1950, Vol. 4, Nos. 2 & 3, pp. 47–53 & 73–80.) A 'control theory' is developed and different applications of feedback are considered as special cases of the basic control circuit.

621.314.3 **1348**

The Magnetic Amplifier.—N. R. Castellini. (*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 151–158.) "The 'small-signal' theory of the magnetic amplifier is developed under certain simplifying assumptions. Expressions for the amplification are derived in terms of electrical and magnetic quantities, and conditions for optimum amplification are obtained. The predictions of the theory are found to agree qualitatively with experimental results of other workers."

621.316.729 **1349**

Synchronization of Quasi-Sinusoidal Oscillators.—G. Francini. (*Alta Frequenza*, June/Aug. 1949, Vol. 18, Nos. 3/4, pp. 125–133. In Italian, with English, French and German summaries.) The equation representing the behaviour of the fundamental types of oscillator is examined by considering the effect of injecting an external voltage or current. By limiting the study to the steady state, and by the use of a simplifying hypothesis, the performance of the oscillator can be determined and, in particular, the limits within which the frequency and amplitude of the applied signal must lie for synchronization to be effected. Various possible circuits for the injection of the synchronizing signal are considered.

621.316.86 **1350**

The Application of Thermistors to Control Networks.—J. H. Bollman & J. G. Kreer. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 20–26.) Equations are developed for the relations between current, voltage, resistance and power in thermistors under steady-state conditions. Voltage/current characteristics are illustrated for directly heated thermistors in series or parallel with external resistance. Their behaviour for zero incremental circuit resistance is studied. The complete differential equation for the time variation of resistance of a directly heated thermistor is obtained in a form which can be solved by use of various linear approximations.

621.318.4 : 621.396.615.17 **1351**

Nonlinear Coil Generators of Short Pulses.—L. W. Hussey. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 40–44). The construction is described of small permalloy coils for the production of pulses of duration $\leq 0.1\ \mu s$ at repetition rates up to a few megacycles/sec. Circuits suitable for various frequency ranges are discussed.

621.318.423.013.78 : 621.3.017.22 **1352**

The Eddy-Current and Screen Losses of a Screened Single-Layer Solenoid.—F. M. Phillips. (*Proc. Instn elect. Engrs*, Part III, March 1950, Vol. 97, No. 46, pp. 77–87.) Butterworth's method for determining the h.f. resistance of an isolated single-layer solenoid is outlined. A modification is proposed which, however, increases the discrepancy between the theory and experimental measurements. The effect of a concentric screening can is also considered and the losses arising in the can itself are calculated. The calculations are in good agreement with Bogle's empirical formula (821 of 1941). The effect of the screening can on the *Q* value is determined for a particular coil for which all the losses are calculated.

621.318.572 **1353**

Speed of Electronic Switching Circuits.—E. M. Williams, D. F. Aldrich & J. B. Woodford. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 65–69.) "Methods of analysis of electronic switching circuits are described which lead to determination of triggering delay and switching wave forms. These methods are illustrated with particular reference to multivibrators."

621.385.12 : 621.318.572 **1354**

The Use of Cold Cathode Relay Valves with Grid-Cathode Circuits of High Resistance.—R. J. Hercock & D. M. Neale. (*Brit. J. appl. Phys.*, Feb. 1950, Vol. 1, No. 2, pp. 53–55.) The grid current drawn by a cold-cathode relay valve near the critical grid potential normally precludes the use of a valve of this type where the grid circuit contains a high series resistance. By superimposing a train of voltage pulses on the applied grid potential this limitation may be removed. The instantaneous grid current may then be high whilst the mean value is much less. The value of the limiting resistance in the grid circuit may then be increased a hundredfold or more. In many cases the pulses may conveniently be derived from the rectifier ripple. Practical applications of the principles are described.

621.39 **1355**

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

9. Transistor Trigger Circuits.—H. J. Reich & P. M. Schulteiss.
12. Mathematical Theory and Applications of Silicon Crystals for Mixing and Harmonic Generation at Microwave Frequencies.—P. D. Strum, J. W. Kearney & J. C. Greene.
28. A Comparison of Frequency and Time Domain Viewpoints in Circuit Design.—W. H. Huggins.
29. Study of Transient Effects by a New Method of Integral Approximation.—M. V. Cerrillo.
30. Applications of the Integral Approximation Method of Transient Evaluation.—W. H. Kautz.
52. Frequency Analysis of Variable Networks.—L. A. Zadeh.
53. Distortion Bandpass Considerations in Angular Modulation Systems.—A. A. Gerlach.
54. Concerning the Lowest Possible Unloaded Resonant Circuit *Q*'s which can be used in Multiple Resonant Circuit Filters.—M. Dishal.
55. Tunable Microwave Waveguide Filters.—W. Sichak & H. A. Augenblick.
56. Filters for Television Interference.—A. M. Seybold.
70. Modern Methods of Servo Synthesis.—R. McCoy & D. Herr.
80. Design of a Hybrid Ring Diplexer for Ultra-High-Frequency Television Use.—W. H. Sayer & J. M. De Bell, Jr.
84. The Design of Diode Gate Circuits.—R. J. Slutz.
88. Monoformer.—A. C. Munster.
93. The Analysis and Design of a Band-Pass Distributed Amplifier.—V. C. Rideout & T. P. Tung.
94. An Investigation of the 400-Mc/s Amplifier Performance of the Type SN-973B Subminiature R.F. Pentode.—N. B. Ritchey.
95. An Extension to Stagger-Tuned Amplifier Design.—J. M. Pettit.
96. Ultra-High-Gain Direct-Coupled Amplifier Circuits.—W. K. Volkers.
97. Analysis and Design of Self-Saturable Magnetic Amplifiers.—S. Cohen.
99. Behaviour of Resistors at High Frequencies.—G. R. Arthur, H. L. Krauss, P. F. Ordung & S. E. Church.
100. Inductors, their Calculation and Losses.—R. F. Field.
101. Transformer Performance and Measurements.—R. Lee.
163. Miniaturization Techniques: A Discussion and Proposal.—M. Abramson & S. Danko.
164. The Exponential-Line Pulse Transformer.—E. R. Schatz & E. M. Williams.
168. The Transient Behavior of a Class-C Oscillator.—C. H. Page.
169. Mode Suppression in Broad-Band Reflex Klystron Oscillators.—A. H. Sonnenschein & H. A. Finke.
170. Telemetering Blocking Oscillator.—W. Todd.
171. Some Aspects of R.F. Phase Control in Microwave Oscillators.—E. E. David, Jr.
172. Seven-League Oscillator.—F. B. Anderson.

621.392 **1356**

Synthesis of Wideband Two-Phase Networks.—H. J. Orchard. (*Wireless Engr*, March 1950, Vol. 27, No. 318, pp. 72–81.) "Hitherto, networks providing a two-phase supply from a single-phase supply over a wide band of frequencies have been designed empirically. A synthesis technique is now available which gives exact design formulae both for the network components and also for the relations between the design parameters. It is shown that the most general circuit meeting the requirement is essentially a pair of all-pass networks. By utilizing elliptic functions, such networks can be designed to have a Tchebycheff approximation to the ideal requirement: this represents the most efficient condition. Simple computing schemes, design curves and a numerical example are included."

621.392 **1357**

Recurrent Network with Inductively Coupled Elements.—G. G. Sacerdote. (*Alta Frequenza*, Dec. 1949, Vol. 18, No. 6, pp. 268–276. In Italian, with English, French and German summaries.) For certain ranges of frequency the operation of such networks with purely reactive elements is analogous to that of networks consisting of elements not purely reactive.

621.392.011.2 **1358**

Reciprocity between Generalized Mutual Impedances for Closed or Open Circuits.—A. G. Clavier. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 69–74.) Equations are developed for the relations between voltages and currents in a pair of open wires of any shape. For sinusoidal voltages, the mutual impedances are reciprocal for closed networks, and also for open wires provided the points of application of voltage and measurement of current are exactly interchanged. Extensions to transient currents and *n* coupled circuits are suggested. Applications to quadripoles, linear aerials and wave projectors are discussed. Limitations of the theory are indicated.

621.392.4.018.12 1359

Realization of a Constant Phase Difference.—S. Darlington. (*Bell Syst. tech. J.*, Jan. 1950, Vol. 29, No. 1, pp. 94–104.) Analysis of the problem of obtaining over a wide frequency range the best approximation to a constant phase difference between the outputs of a pair of constant-resistance phase-shifting networks fed from a common source. The phase variation over a frequency range of ratio ω_2/ω_1 is derived generally for networks of n sections with optimum circuit constants, using Cauer's functions based on a Tchebycheff approximation. The determination of the parameters of the network sections is described.

621.392.41 : 621.317.729 1360

An Electrolytic Tank for the Measurement of Steady-State Response, Transient Response and Allied Properties of Networks.—A. R. Boothroyd, E. C. Cherry & R. Makar. (*Proc. Instn elect. Engrs*, Part III, March 1950, Vol. 97, No. 46, pp. 126–128.) Long summary of 2743 of 1949.

621.392.43 1361

Theoretical Limitations on the Broadband Matching of Arbitrary Impedances.—R. M. Fano. (*J. Franklin Inst.*, Feb. 1950, Vol. 249, No. 2, pp. 139–154.) Conclusion of 1094 of May.

621.392.43 1362

Two-Band Antenna-Matching Networks.—Marshall. (*See* 1339.)

621.392.43 : 621.396.67 1363

Design Procedures for Pi-Network Antenna Couplers.—L. Storch. (*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, p. 158.) Correction to 571 of March.

621.392.5 1364

Method of Calculating the Response of a Linear System to an Arbitrary Stimulus.—M. D. Indjoudjian. (*Ann. Télécommun.*, Feb. 1948, Vol. 3, No. 2, pp. 34–44.) The concept of admittance of a network is generalized by the introduction of a response factor and methods are indicated for determining the response of a system to an arbitrary stimulus from its response to certain particular stimuli. Comparison is made between Fourier series, the Fourier integral and Laplace integral, indicating their fields of application and explaining the successful results obtained by means of the Laplace transformation, closely related to the fact that the Laplace transforms of voltages and currents follow Ohm's law. The most important formulae connected with the Laplace transformation are listed and the method is applied to determine the response of a linear system to an impulsive, transient or suddenly applied sinusoidal stimulus, introducing Heaviside developments in series. The particular case of a low-pass filter is considered. The relation between the continuous spectrum of an isolated signal and the line spectrum of a train of recurrent signals is discussed. Other applications of the Laplace transformation to differential and integral equations and to finite-difference equations are explained.

621.392.52 1365

The Analysis of Broad-Band Microwave Ladder Networks.—M. C. Pease. (*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 180–183.) When line effects are present, analysis of multi-element networks by normal methods is complicated. Pauli spin matrices are applied to structures with 2, 3, 4 or 5 elements, and explicit formulae for the transmission function of quarter-wave coupled filters are derived. Curves for the mid-band $\lambda/4$-spacing case are given; from these the exact voltage s.w.r. of a low-Q filter can be readily calculated.

621.392.52 : 621.315.212 1366

Spurious Modes in Coaxial-Transmission-Line Filters.—D. E. Mode. (*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 176–180.) Poor agreement between observed and calculated lower TEM cut-off frequencies is shown to be due to the transmission of higher, or spurious, modes past the shunt rods, or to resonances occurring when the circumference of either coaxial conductor is a multiple of the wavelength. A more exact method for calculating the TEM cut-off frequencies is given.

621.392.52 : 621.397.82 1367

Eliminating TVI with Low-Pass Filters.—G. Grammer. (*QST*, Feb.–April 1950, Vol. 34, Nos. 2–4, pp. 19–25, 20–25, 104 & 23–30.) Part 1 deals with the installation and operation of amateur transmitting equipment to minimize interference with television reception. Part 2 discusses operating characteristics of filters and practical design considerations. Part 3 describes simplified graphical methods for filter design.

621.392.52.029.63 1368

A Coupled 'Coaxial' Transmission-Line Band-Pass Filter.—J. J. Karakash & D. E. Mode. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 48–52.) Design of a microwave filter formed by two parallel conductors within a conducting cylinder. Expressions are derived for cut-off frequencies, attenuation and impedances, and matching conditions are considered. Experimental results are in fair agreement with theory.

621.392.53 : 621.397.645 1369

The Design of Complex Correcting Circuits for Television Amplifiers.—G. V. Braude, K. V. Epaneshnikov & B. Ya. Klimushev. (*Radiotekhnika, Moscow*, Nov./Dec. 1949, Vol. 4, No. 6, pp. 24–33. In Russian.) The operation of the correcting circuit using inductances in the grid and anode circuits of the valve (Fig. 5) is discussed. Use is made of the method of transient characteristics determining the transmission of a single impulse by the amplifier, and parameters of the circuit are so chosen as to ensure the best compromise between the frequency and phase corrections. The characteristics so obtained are much better than those of a simple circuit (inductance in the anode circuit only) and approach very near the ideal characteristics.

621.395 : 396.665 : 621.3.015.33 1370

Transient Response of a Regulator Chain.—H. Jefferson. (*Wireless Engr*, March 1950, Vol. 27, No. 318, pp. 83–85.) An expression is derived which characterizes the output of a chain of identical automatic level regulators following a change of input level. A system having n sections has an output response characteristic which crosses the reference-level axis $n - 1$ times. The time scale depends only on a constant k, a characteristic of the regulators, but the amplitude is independent of k and depends only on the magnitude of the initial disturbance. Further expressions are derived for the case when k is not the same for all the regulators in the chain, and for the practical case when the integration process is imperfect owing to leakage.

621.396.6 1371

1950 Components Exhibition, Paris.—J. Rousseau. (*T.S.F. pour Tous*, March 1950, Vol. 26, No. 257, pp. 91–96.) Short review with classification of exhibits, and descriptions and illustrations of valves, c.r. tubes, coils, assembled units and capacitors. Other types of equipment will be considered in subsequent articles. For other accounts see *Radio prof., Paris*, Feb. 1950, Vol. 19, No. 181, pp. 20–29, and *Toute la Radio*, March/April 1950, Vol. 17, No. 144, pp. 128–137.

621.396.6 1372

The Design of Electronic Equipment using Subminiature Components.—M. L. Miller. (*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 130–135.) A general survey with particular attention to the heat dissipation of the units and the operating temperatures of the components.

621.396.611.1 : 535.49 1373

Nomographic Determination of Temperature Compensation for Oscillatory Circuits.—H. Geschwinde. (*Funk u. Ton*, Feb. 1950, Vol. 4, No. 2, pp. 85–89.) Values of compensating ceramic capacitors are given by a simple abac.

621.396.611.1.015.3 : 621.3.012 1374

Detuned Resonant Circuits.—D. G. Tucker; H. Elger. (*Wireless Engr*, Feb. 1950, Vol. 27, No. 317, pp. 64–65.) Comment on 1102 of May (Elger) and Elger's reply.

621.396.611.21 1375

Crystal-Controlled Oscillators.—C. V. Chambers. (*QST*, March 1950, Vol. 34, No. 3, pp. 28–33.) An investigation to determine optimum operating conditions using the new small type of crystal in three popular oscillator circuits: (*a*) grid-anode circuit, (*b*) triode-tetrode circuit, (*c*) modified Pierce circuit. Valves used were Types 6AG7, 6F6, 6V6GT and 6L6. Circuits are shown and performance curves are analysed. The 6AG7 was found the best valve from every standpoint. The triode-tetrode circuit gives the highest output and the modified Pierce circuit the lowest crystal current. Screen-voltage regulation is recommended for good keying.

621.396.611.3 : 621.365.5 1376

Output Coupling of Valve Generators for Industrial Heating Purposes.—M. Krüger. (*Arch. Elektrotech.*, 1950, Vol. 39, No. 9, pp. 619–632.) A systematic study of various methods of coupling to the load circuit, particularly transformer coupling, for which graphical design methods are given.

621.396.611.4 1377

On Avoiding Low Frequencies in a Rectangular Cavity Resonator used as Part of a Triode Generator.—K. F. Niessen. (*Appl. sci. Res.*, 1950, Vol. B1, No. 5, pp. 325–340.) Reprint. See 1330 of 1949.

621.396.615 1378

Phase-Shift Oscillator.—W. R. Hinton; W. P. N. Court. (*Wireless Engr*, Feb. 1950, Vol. 27, No. 317, pp. 65–66.) Comments on 324 of February (Vaughan).

621.396.615 1379

On the Design of RC Oscillators.—V. G. Kriksunov. (*Radiotekhnika, Moscow*, Nov./Dec. 1949, Vol. 4, No. 6, pp. 49–58. In Russian.) Several variants of the RC oscillator are examined critically and the advantages of the type in which the feedback voltage from the load resistance is applied to the phase-shift circuit through a cathode follower (Fig. 2) are pointed out. The operation of this type of oscillator is discussed in detail and separate design formulae are derived for the cases when the phase-shift circuit consists of three and four links respectively. Formulae are also derived for determining the frequency stability and amplitude of steady-state oscillations. A diagram is given of the oscillator with which the theoretical conclusions were verified.

621.396.615 1380

Investigations of a Transitron Relaxation Oscillator.—V. V. Migulin & T. N. Yastrebtsova. (*Elektrotechnik, Berlin*, Feb. 1950, Vol. 4, No. 2, pp. 42–45.) German account of 3054 of 1948.

621.396.615.12 : 621.365.5 1381

High-Power, High-Frequency Oscillators for Industrial Uses.—C. Beurthevet. (*Rev. tech. Comp. franç. Thomson-Houston*, Feb. 1950, No. 13, pp. 5–16.) Two design principles have been adopted for simplifying industrial heating apparatus. These are: (*a*) the intermittent operation of valves with high thermal inertia, permitting a tenfold increase of the normal maximum anode dissipation; (*b*) the coupling of thyratron or other rectifiers direct to h.v. polyphase mains. Illustrations of a 12–120-kW and a 50–500-kW generator incorporating these principles are shown.

621.396.619.23 1382

Non-Linear Effects in Rectifier Modulators.—D. G. Tucker & E. Jeynes. (*Wireless Engr*, Feb. 1950, Vol. 27, No. 317, p. 66.) Comment on 2184 of 1949 (Belevitch).

621.396.615.17 1383

High-Power Sawtooth Current Synthesis from Square Waves.—H. E. Kallmann. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 60–64.) 1949 I. R. E. National Convention paper. A high-power sawtooth oscillation may be obtained by adding a series of square waves whose amplitudes and periods decrease as $1/2^n$. For n square waves, the first (2^n-1) harmonics of the true and synthesized sawtooth waves are identical, and a basic circuit using push-pull connections for addition of four square waves is illustrated. The requirements of filters for smoothing the step-ripple of the output are discussed. The efficiency of the basic circuit is <50%, but by a gating system which permits only addition of the current in the 'push' and 'pull' valves, this can be raised to nearly 100%.

621.396.615.17 : 621.315.612.4 1384

Aperiodic Frequency-Doubling by means of 'Pluri-Terminal' Titanate Capacitors.—A. A. Pascucci & H. W. Stawski. (*Nature, Lond.*, 18th March 1950, Vol. 165, No. 4194, p. 441.) The dependence of the permittivity of titanate ceramic dielectrics upon applied field strength holds both for crossed and for parallel superimposed fields. In measurements demonstrating this effect, application of a sufficiently high a.c. voltage to one pair of opposite faces of a parallelepiped of the material, and a polarizing voltage to the orthogonal pair, produced a frequency-doubled output, the fundamental frequency being almost completely suppressed. See also 1612 of 1949 (No. 53: Pascucci).

621.396.645 1385

New High-Efficiency Methods of Amplifying Modulated Oscillations.—N. V. Trunova. (*Radiotekhnika, Moscow*, Nov./Dec. 1949, Vol. 4, No. 6, pp. 63–73. In Russian.) A modified Doherty modulation circuit is proposed in which two modulated channels with a single impedance inverter are provided (Fig. 2). This method is compared with the one used in the Dutch (Nozema) 125-kW transmitter in which four modulated channels with three impedance inverters are used (Fig. 5). The operation of both systems is discussed and the design of the grid circuit is considered in detail. The Nozema system is expensive and gives only a slight increase (from 3 to 6%) in the efficiency. The single inverter system on the other hand ensures a sufficiently high efficiency (approx. 60%) and a low level of nonlinear distortion.

621.396.645 1386

Graphical and Analytical Study of Cathode-Follower Problems.—S. Malatesta. (*Alta Frequenza*, June/Aug. 1949, Vol. 18, Nos. 3–4, pp. 134–147. In Italian, with English, French and German summaries.) Considering anode current as a function of the grid/anode voltage rather than of the grid/cathode voltage, a family of characteristic curves and a set of differential parameters are derived; by means of these, cathode-follower problems can be solved by the conventional methods used for amplifiers.

621.396.645 1387

A New Phase-Inverter Stage for a Push-Pull Amplifier.—J. Lignon. (*T.S.F. pour Tous*, March 1950, Vol. 26, No. 257, pp. 102–105.) Description of a circuit using a double-triode for feeding an aperiodic amplifier. Chief advantages of such a stage are: (*a*) the voltage gain of about 30 dispenses with the need for a driver stage in a l.f. power amplifier; (*b*) the phase relation of the two output voltages remains constant from zero up to several megacycles/sec, so that phase distortion is eliminated.

621.396.645 1388

RC-Coupled Power Stage.—M. G. Scroggie. (*Wireless Engr*, March 1950, Vol. 27, No. 318, pp. 81–82.) Conditions are derived for maximum output.

621.396.645 : 534.85 1389

Phonograph Reproduction: Part 2.—C. G. McProud. (*Audio Engng, N.Y.*, March 1950, Vol. 34, No. 3, pp. 20–22.) Continuation of 1117 of May, giving full details of the preamplifier and equalizer circuits, with a complete list of components, for a control unit to be used with the Musician's Amplifier (70 of January).

621.396.645.37 1390

Combining Positive and Negative Feedback.—J. M. Miller, Jr. (*Electronics*, March 1950, Vol. 23, No. 3, pp. 106–109.) Description, with full circuit details, of a 2-stage a.f. amplifier using a combination of local positive feedback in the first stage and a moderate amount of overall negative feedback. Results of distortion measurements for many different combinations of operating conditions are tabulated and shown graphically. Characteristics approaching those of more complex amplifiers with a greater degree of negative feedback can be obtained.

621.396.822 : 621.316.8 1391

The Linear Theory of Fluctuations Arising from Diffusional Mechanisms — An Attempt at a Theory of Contact Noise.—J. M. Richardson. (*Bell Syst. tech. J.*, Jan. 1950, Vol. 29, No. 1, pp. 117–141.) A general analysis of the power spectral density $S(\omega)$ of the fluctuations of the resistance of a contact which are linearly determined by thermally-excited concentration fluctuations in a diffusing medium. Special physical models are considered and the theoretical spectra derived are compared with Christensen & Pearson's experimental result: $S(\omega) = KV^{a-2}\,\overline{R}^{b+2}\omega^{-1}$, where V is the applied d.c. voltage, $\overline{R}$ the average value of the contact resistance and $a \approx 1.85$, $b \approx 1.26$. A system involving the contact between relatively large areas of rough surfaces covered with diffusing surface layers should have $S(\omega) \propto \omega^{-1}$ and a reasonable dependence of $S(\omega)$ on $\overline{R}$. A refinement of the theory removes the divergence at $\omega = 0$ of the integral of $S(\omega)$. The analysis is intended to elucidate the mechanism of voltage fluctuations in granular resistors, thin films, rectifying crystals and transistors when a d.c. voltage is applied.

GENERAL PHYSICS

53 1392

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

5. News of the Nucleus.—U. Liddel.
76. Scattering of Plane Electromagnetic Waves by a Perfectly Conducting Hemisphere or Hemispherical Shell.—E. Kennaugh.
77. Diffraction by a Prolate Spheroid.—F. V. Schultz.

531.8 : 621.396.619 1393

From Linear to Nonlinear Mechanics.—J. Loeb. (*Ann. Télécommun.*, Feb. 1950, Vol. 5, No. 2, pp. 65–71.) By analogy with the linear transformation of a telecommunication signal by a nonlinear system, the modulator, a similar process can be used to linearize nonlinear electromechanical or mechanical systems such as relays, radiogoniometers, etc. A 'sweep function' in this case serves the same purpose as the radio carrier wave.

534.2 + 538.566 1394

Field Due to a Point Radiator in a Medium of Non-Homogeneous Layers.—L. M. Brekhovskikh. (*Bull. Acad. Sci. U.R.S.S., sér. phys.*, Sept./Oct. 1949, Vol. 13, No. 5, pp. 505–545. In Russian.) In previous papers the author investigated the propagation of sound and e.m. waves in layers with plane parallel boundaries. In the present paper the more general case is considered of a layer, the upper and lower boundaries of which are not sharply defined. A new method is proposed for determining the field due to a point radiator. In this method the radiated spherical wave is resolved into a number of plane waves and the propagation of each of these is examined separately. Equations determining the propagation of the waves are derived and their solutions found in the form of integrals. These integrals are discussed in detail and it is shown that the results obtained can be presented in a form suitable for calculation. Different combinations of waves become predominant at different distances from the radiator. The dependence of the sound pressure or intensity of the e.m. field on distance from the radiator is determined. Illustrative examples are given.

537.291 + 538.691] : 621.385.029.63/.64 1395

Electron Beams in Axially Symmetrical Electric and Magnetic Fields.—C. C. Wang. (*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 135–147.) Equations are obtained for the trajectories of electrons along the outer edges of beams for the general case in which both axial and radial fields are present. The effects of the combined fields can be expressed as a single generalized potential function depending only on the axial and radial space coordinates, thus permitting the force components to be expressed as components of the gradient of the potential function. Numerical solutions are obtained and normalized curves are given for practical cases. An equilibrium radius exists for which the net radial forces acting on the electron are zero and the outer radius of the beam oscillates about this value, the amplitude being nonsymmetrical and the distance between successive maxima depending on the amplitude.

538.322 1396

Attraction between Two Parallel Currents of Unlimited Length.—A. Liénard. (*J. Phys. Radium*, Jan. 1950, Vol. 11, No. 1, pp. 1–6.) The degree of approximation of known formulae for the force of attraction is determined by combining Kelvin's inversion method and the Schwartz method of alternation. Making use of the fact that the field around each conductor is the same as that due to doublets comprising two equal and opposite currents, an expression for the attraction is derived in the form of a rapidly converging series. Simple modifications of the formulae are indicated for the case in which the medium surrounding the conductors is not a vacuum.

538.56 : 537.71 1397

The Intrinsic Impedance of Space.—T. Tanasescu: E. Brylinski. (*Wireless Engr*, Feb. 1950, Vol. 27, No. 317, pp. 63–64.) Further discussion. See also 607 of March (Budeanu), 876 of April (Foch) and 877 of April (Brylinski).

538.569.4 : 523.755 **1398**

On the Absorption of Radio Waves in the Solar Corona.—V. L. Ginzburg. (*Astronom. Zh.*, March/April 1949, Vol. 26, No. 2, pp. 84–96. In Russian.) Formulae for the absorption of radio waves in an ionized gas are discussed; they may be applied to the ionosphere, the solar corona and the interstellar gas. Differences between the absorption of radio waves and light waves are considered. The 'radiative depth' of the solar corona for wavelengths in the range 0.6–50 m is determined and the results are tabulated. Discussion of the effect of magnetic fields shows that both the ordinary and extraordinary waves are elliptically polarized and that they originate from different layers and can have very different intensities.

537.212 + 538.12 **1399**

Electric and Magnetic Fields. [Book Review]—S. S. Attwood. Publishers: Chapman & Hall, London, and J. Wiley & Sons, New York, 3rd edn 1949, 475 pp., 44s. or $8.50. (*Wireless Engr*, March 1950, Vol. 27, No. 318, p. 94; *Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, p. 191.) Intended to provide "training in the development of the fundamental concepts, formulas, terminology, and units used in electric and magnetic field study." "The rationalized m.k.s. system of units has been adopted, but tables are given showing the relations between the units in the various systems."

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.72 : 621.396.812.3 **1400**

Sudden Enhancements [of atmospherics] **on Very Long Waves.**—Bureau. (*See* 1499.)

523.72.029.64 : 621.396.822 **1401**

Distribution of Radiation from the Undisturbed Sun at a Wave-Length of 60 cm.—H. M. Stanier. (*Nature, Lond.*, 4th March 1950, Vol. 165, No. 4192, pp. 354–355.) Measurements made at this wavelength with spaced aerials showed that no apparent increase in radiation occurs at the limb and the intensity there is about 60% of that near the centre of the disk. About 30% of the total radiation comes from the region outside the visible disk.

523.74 : 621.396.11 **1402**

Unusual Ionospheric Storm.—Bennington. (*See* 1500.)

523.755 **1403**

The Solar Corona.—H. v. Klüber. (*Elektron. Wiss. Tech.*, March 1950, Vol. 4, No. 3, pp. 77–88.) Observations made during eclipses are reviewed and the temperature and electron distribution in the corona are studied. Radiation intensity at different wavelengths is discussed. The "betatron theory" may explain the heating of the corona to a temperature 10^8 degrees above that of the sun's surface, 6 000 degrees.

523.755 : 538.569.4 **1404**

On the Absorption of Radio Waves in the Solar Corona.—Ginzburg. (*See* 1398.)

523.856 : 621.396.822 **1405**

Point Sources of Radio Noise.—D. H. Menzel & D. J. Crowley. (*Nature, Lond.*, 18th March 1950, Vol. 165, No. 4194, p. 443.) A brief discussion of the origin of noise observed in radio-astronomy. It is tentatively suggested that the point sources may be comets within the solar system, which absorb ionizing energy from the sun and re-radiate it after conversion.

551.510.535 + 621.396.1 **1406**

Physical Society Conference [on the ionosphere] **at Cambridge, 14th to 16th July 1949.**—(*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, pp. 141–150.) Abstracts are given of 17 papers presented at the conference; these are all noted below, in this section or in the 'Propagation of Waves' section.

551.510.535 **1407**

Theoretical Considerations regarding the Formation of the Ionized Layers.—D. R. Bates & M. J. Seaton. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, pp. 129–140.) Physical Society Summer Conference paper. The detailed mechanisms involved in the formation of the E, F_1, F_2 and D layers by solar ultraviolet radiation are discussed. Use is made of the results of some recent calculations on the continuous absorption cross-section of atomic oxygen and nitrogen, and of the evidence on the ionic composition of the layers that is provided by the analysis of the emission spectrum of the upper atmosphere during twilight. The uncertainties existing at present are emphasized.

551.510.535 **1408**

The Formation of the Ionized Regions.—K. Weekes. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, pp. 147–148.) Summary of Physical Society Summer Conference paper. Close comparison of observed results with Chapman's simple theory of absorption of ultraviolet light in an isothermal atmosphere reveals discrepancies, examination of which leads to a revision of the assumption that the electron recombination rate is independent of gas pressure. Gases which may be concerned in the various layers are discussed.

551.510.535 **1409**

Irregularities in the Horizontal Plane in Region E of the Ionosphere.—J. W. Findlay. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, p. 148.) Summary of Physical Society Summer Conference paper. Experiments are described for measuring phase and amplitude variations of 2.4-Mc/s signals reflected from region E at vertical incidence, and the rapidity of phase fluctuation is taken as a measure of the irregularity of the reflecting region; daily and seasonal variations of this irregularity are shown. Measurements of the amplitudes of pulse signals returned to three ground receiving points about 100 m apart fit in with the assumption that the irregularities in region E have at any time random motions among themselves and also an overall horizontal drift. Theories are developed for determining these motions.

551.510.535 : 523.5 **1410**

Meteor Ionization in the Upper Atmosphere.—A. C. B. Lovell. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, p. 149.) Summary of Physical Society Summer Conference paper. Recent progress in the study of the scattering of radio waves from meteor trails is described. Two significant facts are (*a*) the discovery of the great daytime meteor radiants active from May to September, and (*b*) the appreciation that only about 10^{-6} of the energy of the meteor is spent in ionization. Reflections from meteor trails have been investigated at various high frequencies, and it is established that all transient echoes in the altitude range 80 to 120 km are due to meteor ionization.

551.510.535 : 523.75 **1411**

Irregular Behaviour of the Ionosphere Associated with Solar Events.—W. R. Piggott. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, p. 146.) Summary of Physical Society Summer Conference paper. Phenomena occurring in the lower regions of the ionosphere associated with solar flares are briefly discussed; the types of experimental data obtained are summarized, and the geophysical significance of the results is indicated. Two main types of ionospheric disturbance are identified, viz., type A, quasi-auroral, and type R, regular. Type A produces marked effects in the F region, associated with fluctuations in the local magnetic field; its relaxation time is a few minutes to one or two hours. Type R

consists of a positive phase (ionization density above normal) and a negative phase (ionization density below normal and recovering); *it has not been found* to be connected with magnetic variations; its relaxation time may be some hours or days.

551.510.535 : 621.396.11 1412

Scattering of Radio Waves from Region E.—Millington. (*See* 1488.)

551.510.535 : 621.396.11 1413

Scattered Echoes Near the Critical Frequencies of the F_2 region.—Rivault. (*See* 1487.)

551.510.535 : 621.396.81 1414

Measurements on Long and Very Long Waves.—Bracewell. (*See* 1495.)

551.510.535 (98) 1415

(P', f) Records at Spitsbergen.—A. B. Whatman. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, p. 145.) Summary of Physical Society Summer Conference paper. Sixty (P', f) records are shown, made with Admiralty Type-249 equipment in Spitsbergen in 1942–1943. These illustrate all the interesting normal and abnormal effects met with and supplement those recently published (2796 of 1949).

LOCATION AND AIDS TO NAVIGATION

621.396.9 1416

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, *No. 2*, pp. 192–211.) Summaries are given of the following papers:

18. The Statistical Properties of Noise Applied to Radar Range Performance.—S. M. Kaplan & R. W. McFall.
61. Antenna System for Very-High-Frequency Radio Ranges and Direction Finding.—F. J. Lundburg & F. X. Bucher.
120. Measurement and Analysis of Noise in a Fire-Control Radar.—R. H. Eisengrein.
143. Analysis of Course Errors in the V.H.F. Omnidirectional Radio Range.—J. W. Leas.
144. Dynamic Aspect of Errors in Radio Navigation Systems, particularly in Case of Fast-Moving Receivers and Transmitters.—H. Busignies.
145. A New Basis for Analyzing Radio Navigation and Detection Systems.—N. L. Harvey.
146. Stochastic Processes as applied to Aerial Navigation and Direction Finders.—L. A. de Rosa.
147. 1 000-Mc/s Crystal-Controlled Airborne Transmitter for Distance Measuring Equipment.—B. Warriner.

621.396.9 : 371.3 1417

Aids to Training — The Design of Radar Synthetic Training Devices for the R.A.F.—G. W. A. Dummer. (*Proc. Instn elect. Engrs*, Part III, March 1950, Vol. 97, No. 46, pp. 124–125.) Discussion on 2230 of 1949.

621.396.93 1418

Fixed H-Adcock Direction Finder for V.H.F.—B. G. Pressey & G. E. Ashwell. (*Wireless Engr*, Feb. 1950, Vol. 27, No. 317, pp. 54–58.) "The paper describes an investigation into the practicability of the fixed type of H-Adcock direction finder for use at very high frequencies (30–100 Mc/s) under conditions in which the aerial system is remote from the operator. The experimental equipment consisted essentially of two crossed H-Adcock aerials mounted on a wooden tower 10 m high. The aerial system was connected by r.f. transmission lines to a goniometer and receiver situated in a hut near the base of the tower. By making adjustments to the length of the transmission lines and their point of connection to the aerial feeders a high instrumental accuracy was obtained on signals of mixed as well as vertical polarization. The sensitivity was such that bearings with a silent swing of $\pm 5°$ could be taken on field strengths varying between 0.5 and 14 μV/m over the frequency range."

621.396.93 1419

The Specification and Measurement of Polarization Errors in Adcock-Type Direction Finders.—W. Ross. (*Elektrotechnik, Berlin*, March 1950, Vol. 4, No. 3, pp. 90–92.) German version of 3143 of 1949.

621.396.93 : 621.396.11 1420

The Effects of Sky-Wave on the Planning of Navigational Aids using Frequencies in the 70–130 kc/s Band.—Sanderson. (*See* 1490.)

621.396.93 : 621.396.11 1421

The Characteristics of Low-Frequency Radio Waves Reflected from the Ionosphere, with particular reference to Radio Aids to Navigation.—Williams. (*See* 1489.)

621.396.93 : 621.396.11.029.58 1422

Very-Low-Frequency Propagation.—Smith & Tremellen. (*See* 1493.)

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788 1423

Construction and Applications of a New Design of the Philips Vacuum Gauge.—F. M. Penning & K. Nienhuis. (*Philips tech. Rev.*, Oct. 1949, Vol. 11, No. 4, pp. 116–122.) By modification of the electrode structure of the original design (1525 and 4265 of 1937) the range of the instrument has been extended to below 10^{-6} mm Hg. Its application as a leak detector is described.

535.215.4 1424

The Photoconductivity of Bismuth Sulphide and Bismuth Telluride.—A. F. Gibson & T. S. Moss. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362A, pp. 176–177.) Independent investigations by the two authors on Bi_2S_3 and Bi_2Te_3 photoconductive and photovoltaic layers of considerable sensitivity do not confirm the suggestion made by Fink & Mackay (U.S. Patent No. 2 406 139, 1946) that these substances may be photosensitive to wavelengths as great as 7μ. The measurements indicate that the Bi compounds behave in a similar way to the corresponding Pb compounds but are inferior to them.

535.37 1425

The Fluorescence of Zinc Sulphide Activated with Copper.—F. A. Kröger, J. E. Hellingman & N. W. Smit. (*Physica, 's Grav.*, Dec. 1949, Vol. 15, Nos. 11/12, pp. 990–1018. In English.) Experimental study, using controlled atmospheres at different temperatures, of the variation in the relative concentration of the fluorescence and quench centres with the conditions of preparation. Effects of refiring at a lower temperature are described. The physical behaviour of the system is discussed on the basis of the Schön-Klasens theory of energy transfer between centres.

537.122 : 621.315.6 1426

Time Dependence of Electronic Processes in Dielectrics.—H. Fröhlich & J. O'Dwyer. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362A, pp. 81–85.)

537.228.1 : 548.0 1427

Superpolarizable (Piezoelectric) Materials.—E. Granier. (*Rev. gén. Elect.*, Jan. 1950, Vol. 59, No. 1, pp. 33–45.) Study of the dielectric, hysteresis and piezoelectric properties of crystals derived from Rochelle salt.

537.228.1 : 548.0 1428

On the Ferroelectricity of KH_2PO_4 and KD_2PO_4 Crystals.—J. Pirenne. (*Physica, 's Grav.*, Dec. 1949, Vol. 15, Nos. 11/12, pp. 1019–1022. In English.) A new theory is proposed to explain the unusual isotopic effect observed with these crystals.

537.529 1429

The Time Delay in Conduction and Breakdown Processes in Amorphous Solids.—J. H. Simpson. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362A, pp. 86–100.) Theoretical determination of the time delay from Fröhlich's theory, and comparison with experimental values.

539.23 : 537.311.31 1430

The Resistivity of Thin Metallic Films.—R. A. Weale. (*Proc. phys. Soc.*, 1st Feb. 1949, Vol. 62, No. 350A, pp. 133–136.) A formula derived for the effective temperature coefficient α' of resistivity indicates that for a film of certain thickness x' will be zero and will be negative if the thickness is further reduced. Negative values are to be expected for comparatively thick films of Bi, in which the mean free path of the electrons is exceptionally long. The formula also shows that the temperature at which α' is zero is lower the thicker the film. The results of van Itterbeek & de Greve (343 and 3305 of 1946) for Ni films are in good agreement with the formula.

539.23 : 537.311.31 1431

Conductivity of Thin Metallic Films.—D. A. Wright: R. A. Weale. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362A, pp. 173–175.) Wright disagrees with Weale's treatment of the problem and points out that according to Appleyard & Lovell (1940 of 1937) metallic films, however thin, should have a positive temperature coefficient. Semiconductor effects could explain the existence of a negative coefficient below a certain temperature. Weale indicates a way of reconciling the two points of view.

620.197 1432

Tropicalization of some Materials and Assemblies used in the Construction of Valves.—G. Trebuchon. (*Le Vide, Paris*, Jan. & March 1950, Vol. 5, Nos. 25 & 26, pp. 748–752 & 777–780.) Discussion of materials affected, various specifications of methods to meet different conditions of use, test methods, and practical techniques.

621.3.011.5 : 532 1433

Refractive Indices and Dielectric Constants of Liquids and Gases under Pressure.—J. S. Rosen. (*J. chem. Phys.*, Dec. 1949, Vol. 17, No. 12, pp. 1192–1197.) Interpolation formulae are discussed.

621.3.011.5 : 546.815.831 + 546.431.831 1434

Dielectric Properties of Lead Zirconate and Barium-Lead Zirconate.—S. Roberts. (*J. Amer. Ceram. Soc.*, 1st Feb. 1950, Vol. 33, No. 2, pp. 63–66.) Methods are described for preparation of ceramic samples. The dielectric properties are measured at 1 Mc/s in the temperature range 25° to 350° C for samples with different proportions of lead and barium. High dielectric constants, of the order of 7 000, are obtainable even at room temperatures. Nonlinear dielectric properties and piezoelectric effects are also investigated.

621.315.61.011.5.029.62/.64 : 621.317.335.3 1435

Measurement of Dielectric Constant and Power Factor at Ultra-High Frequencies.—Briganti. (*See* 1452.)

621.385.032.21 + 666.1.037.5 1436

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

158. A Vacuum Seal between Metals and Ceramics for High Temperature Applications.—H. W. Soderstrom & K. H. McPhee.
159. Effect of Coating Composition of Oxide-Coated Cathodes on Electron Emission.—E. G. Widell & R. A. Hellar.
160. Effects of Controlled Impurities in Nickel Core Metal on Thermionic Emission from Oxide-Coated Cathodes.—G. Hees.
161. Investigation of Contaminant in Vacuum Tubes.—P. D. Williams.
162. Hot Strength Properties of Filamentary Alloys.—B. Wolk.

666.968 : 621.315.612.6 : 621.315.613.1 1437

Vacuum-Tight Sealing of Glass and Mica.—J. Labeyrie. (*J. Phys. Radium*, Jan. 1950, Vol. 11, No. 1, p. 20.) Mica laminae as thin as 0.01 mm can be sealed to glass by means of a powdered enamel (G50) which softens at 354° and melts at 550°C. The same enamel may be used to seal mica to alloys with coefficients of expansion between 85 and 110 × 10^{-7} per degree C.

MATHEMATICS

51 : 621.396 1438

Mathematics in Radio.—E. Roubine. (*Rev. tech. Comp. franç. Thomson-Houston*, Feb. 1950, No. 13, pp. 17–32.) The subject is considered from two aspects: (*a*) the assistance given to the technician by different branches of mathematics; (*b*) the application of radio principles in the solution of mathematical problems. The processes of classical analysis, symbolic, tensorial, and matrix calculus, and infinitesimal geometry are outlined. Examples are given of their use. The principles of servomechanisms and computing machines are briefly examined. As an example of the difficulties which may occur in the application of analytical methods, the case of the cylindrical dipole radiator is discussed.

517.56 : 621.3 1439

Origin and Meaning of Circular and Hyperbolic Functions in Electrical Engineering.—A. Boyajian. (*J. Franklin Inst.*, Feb. 1950, Vol. 249, No. 2, pp. 117–131.)

517.9 1440

Determination of the Stable Periodic Solutions of Certain Quasi-Harmonic Differential Equations.—T. Got. (*C. R. Acad. Sci., Paris*, 13th Feb. 1950, Vol. 230, No. 7, pp. 612–614.)

681.142 1441

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp.192–211.) Summaries are given of the following papers:

83. Static Magnetic Pulse Control and Information Storage.—An Wang.
84. The Design of Diode Gate Circuits.—R. J. Slutz.
85. Marginal Checking as an Aid to Computer Reliability.—N. H. Tayler.
86. Development of the California Digital Computer.—D. R. Brown & P. L. Morton.
90. M.I.T. Electrostatic Storage Tube.—S. H. Dodd, H. Klemperer & P. Youtz.
117. A Discussion revealing some Late Developments in Electronic Analog Computer Techniques.—H. I. Zagor.
118. An Electronic Storage System.—E. W. Bivans & J. V. Harrington.
119. Experimental Determination of System Functions by the Method of Correlation.—J. B. Wiesner & Y. W. Lee.
121. A Digital Electronic Correlator.—H. E. Singleton.
166. A Compact Magnetic Memory.—P. L. Morton.

681.142 1442

Electrical Computer for Higher-Order Equations.—H. Glubrecht. (*Z. angew. Phys.*, Jan. 1950, Vol. 2, No. 1, pp. 1–8.) Seventh-order equations of the general form $w = a_7 \cdot z^7 + a_{7-1} \cdot z^{7-1} + \ldots + a_1 \cdot z + a_0 = 0$ may be solved by the apparatus described. The unknown complex quantity z is represented by two sinusoidal

oscillations with a phase difference of 90°. By combining the proposals of Tischner and Rasch, the z and w planes are displayed on a c.r. tube screen and the passage of the polar curves through zero is used to give the solution points in the z plane.

681.142 **1443**

On a General Type of Algebraic Mathematical Machine.—F. H. Raymond. (*Ann. Télécommun.*, Jan. 1950, Vol. 5, No. 1, pp. 2–20.) Further discussion of Type-OME machines (919 of April), their principles and applications. Type OME 14 can solve up to 10 simultaneous equations and uses one matrix of linear potentiometers. Types OME 12 and OME 13 use four such matrices and are designed for the solution of integro-differential equations.

501 **1444**

Introduction to Applied Mathematics. [Book Review]—F. D. Murnaghan. Publishers: Chapman & Hall Ltd, London, 1948, 389 pp., 30s. (*Beama J.*, Jan. 1950, Vol. 57, No. 151, pp. 12–13.) "The standard of the book is that of a graduate course in applied mathematics." It is the first of a series to be published on mathematical theories underlying physical science and on advanced mathematical techniques required for the solution of scientific problems. A "well-printed, well-produced" volume "suited to the needs of scientific workers in mathematics, physics, chemistry, and engineering."

517 **1445**

Höhere Mathematik für Mathematiker, Physiker, Ingenieure. [Book Review]—R. Rothe. Publishers: B. G. Teubner Verlagsg., Leipzig. Vol. 1: Differential Calculus and Basic Formulae of Integral Calculus, with Applications. 8th edn 1948, 208 pp., 6.20 DM. Vol. 2: Integral Calculus, Infinite Series, Vector Calculus, with Applications. 6th edn 1949, 208 pp., 6.20 DM. Vol. 4: Exercises with Solutions, Nos. 1/2, 5th edn 1949, 109 pp., 3.50 DM. Nos. 3/4, 4th edn 1949, 108 pp., 3.40 DM. (*Elektrotechnik, Berlin*, Feb. 1950, Vol. 4, No. 2, p. 64.)

MEASUREMENTS AND TEST GEAR

529.78 : 621.396.91 **1446**

The Synchronization of Clocks by means of Periodic Signals.—M. Lavet. (*Rev. gén. Elect.*, Jan. 1950, Vol. 59, No. 1, pp. 22–32.) Past and present systems of time-signal transmissions are reviewed and their application in various branches of science and industry is discussed. Methods are described for applying the accurate time signals now available to the synchronization of master clocks and recording chronometers, and to the regulation of ancient pendulum clocks in church towers or public buildings.

529.786 + 621.3.018.4(083.74) **1447**

Adjustment of High-Precision Frequency and Time Standards.—J. M. Shaull. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 6–15.) The basic equipment used by the C.R.P.L. of the National Bureau of Standards for broadcasting standard frequency and time signals is described and the application of these signals in the calibration of similar equipment is discussed. Several methods are described for checking the frequency of precision oscillators and the performance of precision clocks. Methods of recording performance data for such standards are suggested. Expected improvements in constancy and accuracy, and possible changes in the types of standards used in time measurement, are considered.

539.16.08 : 621.083.72 **1448**

A Pulse-Amplitude Analyser of Improved Design.—E. H. Cooke-Yarborough, J. Bradwell, C. D. Florida & G. A. Howells. (*Proc. Instn elect. Engrs*, Part III, March 1950, Vol. 97, No. 46, pp. 108–121.) A discussion of the requirements and a detailed description are given of an instrument designed to measure the amplitude distribution of pulses in an ionization chamber or other source. There are five channels, so that the pulses are divided into five groups of different level. The instrument consists of an amplifying and pulse-expanding unit, a ladder sorting circuit, and five scaling units and registers. The circuits include a combined discriminator and cancelling circuit, and an automatic d.c. level control, which are new and contribute effectively to stability and simplicity of adjustment.

621.317.089 : 621.3.012 **1449**

A Modern Electroacoustic Frequency-Response Recording Unit.—H. Lehner. (*Funk u. Ton*, Feb. 1950, Vol. 4, No. 2, pp. 53–65.) The construction and operation of the instrument are described. Impedances of passive 2-pole networks, quadripole and transmission-line attenuations, microphone and loudspeaker response curves can be recorded automatically.

621.317.32 **1450**

A Negative-Feedback D.C. Amplifier with D.C.-Polarized Chokes and Grid-Controlled Valves.—W. Geyger. (*Arch. tech. Messen*, Feb. 1950, No. 169, pp. T22–T24.) An instrument is described in which the direct voltage to be measured is applied to the control windings of a magnetic amplifier and is opposed by the voltage across a compensating resistor in the circuit of a moving-coil recorder. The recorder is operated from a symmetrical double-triode circuit to which the output from the magnetic amplifier is applied. The range of the instrument is from zero to 0.5 mV.

621.317.321.027.2 **1451**

Method of Measurement of Small Direct Voltages.—H. H. Rust & H. Endesfelder. (*Z. angew. Phys.*, Jan. 1950, Vol. 2, No. 1, pp. 39–41.) The method consists in converting the direct voltage into a proportionate alternating voltage. A carbon microphone is energized by the voltage to be measured and responds to tone of constant frequency and amplitude from a loudspeaker. By suitable amplification of the microphone output, voltages down to 1 μV can be measured. Variable direct voltages may be measured if their pulsation frequency is lower than that of the tone source.

621.317.335.3 : 621.315.61.011.5.029.62/.64 **1452**

Measurement of Dielectric Constant and Power Factor at Ultra-High Frequencies.—E. Briganti. (*Alta Frequenza*, Dec. 1949, Vol. 18, No. 6, pp. 243–253. In Italian, with English, French and German summaries.) Description of a method of measurement based on determining the Q factor of a coaxial transmission line sustaining standing waves, with and without the dielectric. Simple formulae are given for calculating dielectric constant and power factor from the different lengths of the resonant line. Results obtained on 10-cm and 22.5-cm wavelengths are given for a few modern insulating materials.

621.317.361 : 621.396.611.21 **1453**

Crystal Resonators as Frequency Substandards.—F. J. M. Laver. (*Proc. Instn elect. Engrs*, Part III, March 1950, Vol. 97, No. 46, pp. 93–99.) The phase response of a crystal resonator is a more sensitive indication of its resonance point than the amplitude response. Equipment using the phase-difference principle is described which enables the resonance frequency of quartz vibrators of frequency 100 kc/s ± 10 c/s to be determined to ± 1 part in 10^8, provided that the Q factor of the vibrator is greater than 10^5. Some results of long-period tests of vibrators with this equipment are given. Quartz resonators may usefully supplement the oscillator units of a large frequency-standard installation.

621.317.7 1454

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

19. Accelerated Life Testing of Vacuum Tubes.—J. Rothstein.
20. Statistical Evaluation of Life Expectancy of Vacuum Tubes Designed for Long Life Operation.—E. M. McElwee.
26. Specification for Quality of the Visual Output of Picture Tube Screens.—A. E. Martin.
42. Oscillographic Presentation of Time Delay and Distortion in Broad-Band F.M. Systems.—A. R. Vallarino.
44. New Test Equipment for the U.H.F. Television Band.—J. Ebert & H. A. Finke.
45. Direct Reading Phasemeter.—L. H. O'Neill & J. L. West.
46. Measuring Procedure for Radioteletype Converters.—H. C. Hawkins.
98. Performance Measurement of Capacitors.—H. T. Wilhelm.
101. Transformer Performance and Measurements.—R. Lee.

621.317.71 1455

New Method of Measurement of Very Heavy Direct Currents.—R. Servant. (*Rev. gén. Elect.*, Jan. 1950, Vol. 59, No. 1, pp. 45–47.) Two flat arms at right angles, with hyperbolic profiles, are pivoted at the vertex and serve as formers for special windings fed by an auxiliary current source adjustable within wide limits. When held so that a conductor carrying heavy current is included in the angle between the two arms, the device is subjected to a couple proportional to the cable current and this couple is neutralized by adjustment of calibrated torsion springs. Partial readings obtained at various positions around the conductor are added. Currents in the range 1–10 kA can be measured.

621.317.733 : 621.317.37 1456

Development of Bridges for Dielectric Measurements.—T. Gast. (*Z. angew. Phys.*, Jan. 1950, Vol. 2, No. 1, pp. 41–48.) A review of a.c. bridges from the fixed-frequency hand-operated instrument to the fully-automatic two-component bridge with a wide frequency range. An automatic system of loss equalization for a pure capacitance bridge by means of an auxiliary current is described.

621.317.733.029.62/.63 1457

Two Simple Bridges for Very-High-Frequency Use.—D. D. King. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 37–39.) Two bridges for impedance measurement are described: (*a*) a hybrid junction tunable over the range 100–500 Mc/s and capable of great sensitivity; (*b*) an untuned Wheatstone bridge for use in the same frequency range. Design features and performance characteristics are given for both units.

621.317.755 1458

Simple Cathode-Ray Oscilloscope.—M. G. Scroggie. (*Wireless World*, March 1950, Vol. 56, No. 3, pp. 82–83.) Design details of a circuit comprising tube controls, variable-frequency timebase and single-valve amplifier. The timebase operates at frequencies from 12 c/s to 40 kc/s, while the amplifier has a flat response over the range 20–20 000 c/s and a continuously variable gain up to about 41 db at a.f. and to 26 db at higher frequencies.

621.317.755 1459

An Easily Portable Cathode-Ray Oscillograph.—E. E. Carpentier. (*Philips tech. Rev.*, Oct. 1949, Vol. 11, No. 4, pp. 111–115.) Description of the Type-GM3655 c.r.o. of dimensions $4\frac{1}{2} \times 11\frac{1}{2} \times 9\frac{1}{2}$ in. and weight 14 lb. The normal frequency limit is 100 kc/s. Separate amplifiers are used for the horizontal and vertical deflections.

621.317.755 : 621.396.6.001.4 1460

Curve Tracer with Electronic Graph Lines.—J. W. Balde, J. C. Bregar & K. L. Chapman. (*Electronics*, March 1950, Vol. 23, No. 3, pp. 100–103.) The response curve of the apparatus under test is displayed on the screen of a c.r.o. together with marker lines indicating the tolerance limits. Only a short time is required to adapt the equipment for testing a different type of apparatus. Production testing and adjustment of filters, amplifiers, discriminators, etc., are greatly facilitated.

621.317.755.089.6 1461

The Dynamic Sensitivity and Calibration of Cathode-Ray Oscilloscopes at Very-High Frequencies.—H. E. Hollmann. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 32–36.) The basic formula for dynamic sensitivity in terms of the transit-time angle of electrons in the deflecting field is modified to take account of (*a*) their displacement on leaving the field and (*b*) stray-field effects. Good agreement with experimental values is obtained.

621.317.761 1462

Measuring a Varying Frequency.—R. L. Chase. (*Electronics*, March 1950, Vol. 23, No. 3, pp. 110–112.) A pulse-shaping circuit is used to convert the wave of unknown frequency to a series of sharp pulses. Measurement is initiated by an external starting pulse and the number of cycles of a standard 5-Mc/s oscillator occurring in an interval corresponding to a selected integral number of the derived pulses is counted. Frequencies in the range 100 kc/s–5 Mc/s can be measured to within 0.1% in about 200 μs. The equipment was designed to measure the frequency of the r.f. oscillator in a l.m. particle accelerator, but many other applications are possible.

621.395.813.083 1463

Intermodulation Distortion.—T. Roddam. (*Wireless World*, April 1950, Vol. 56, No. 4, pp. 122–125.) A simplified method of measurement not requiring a harmonic analyser.

621.396.615 : 621.316.726.078.3 1464

A Variable-Frequency Oscillator stabilized to High Precision.—L. F. Koerner. (*Bell Lab. Rec.*, Feb. 1950, Vol. 28, No. 2, pp. 66–71.) The oscillator is stabilized by locking to a combination of the *n*th harmonic of a standard frequency source and a l.f. interpolation oscillator. This stabilized frequency may then be multiplied by means of a harmonic generator. The ultimate accuracy is limited only by that of the frequency standard. Curves obtained by means of the equipment are given showing the response of a quartz-crystal network for frequencies near its 10-Mc/s fundamental and third harmonic.

621.396.822 : 621.316.8 1465

Resistor Noise.—E. Paolini & G. Canegallo. (*Alta Frequenza*, Dec. 1949, Vol. 18, No. 6, pp. 254–267. In Italian, with English, French and German summaries.) Study of the noise produced by spontaneous voltage fluctuations across resistors of different types. Two instruments for measurement of such noise are described.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

535.322.1 : 539.165 1466

Theory of a Magnetic Lens Type Beta-Ray Spectrometer.—N. F. Verster. (*Appl. sci. Res.*, 1950, Vol. B1, No. 5, pp. 363–378.)

539 + 621.3 **1467**

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

6. Particle Accelerators.—M. S. Livingston.
7. Radio-Frequency Problems associated with Particle Accelerators.—J. P. Blewett.
8. Detection of Nuclear Radiations.—J. R. Dunning.
43. Rockets Range Instrumentation.—E. R. Toporeck & F. M. Ashbrook.
51. Industrial Television System.—R. C. Webb & J. M. Morgan.
64. A High-Capacity Matrix-Commutated Radio Telemetering System.—J. P. Chisholm, E. F. Buckley & G. W. Farnell.
67. Use of Image Converter Tube for High-Speed Shutter Action.—A. W. Hogan.
68. Ultrasonic Pulse Instruments for Automatic Continuous Measurement of Physical Properties of Solids and Liquids.—S. R. Rich.
69. Electronic Duplicator Attachments for Automatic Machine Tool Operation.—W. Roth.
70. Modern Methods of Servo Synthesis.—R. McCoy & D. Herr.
71. An Electronic Flowmeter and its Industrial Applications.—E. Mittelmann & V. J. Cushing.
132. Effects of Intense Microwave Radiation on Living Organisms.—J. W. Clark.
133. A Differential Vectorcardiograph.—S. A. Briller & N. Marchand.
134. Electronic Mapping of the Electrical Activity of the Heart and Brain.—S. Goldman.
167. Synchro-Cyclotron Field Regulator.—C. S. McKown & W. P. Caywood, Jr.

539.16.08 **1468**

Fluctuations in Proportional Counters.—W. F. G. Swann. (*J. Franklin Inst.*, Feb. 1950, Vol. 249, No. 2, pp. 133–137.)

621.3.07 + 621.396.645.37 **1469**

Control, Positive and Negative Feedback and Negative Resistance Coordinated.—Reichardt. (*See* 1347.)

621.365.5 : 621.396.611.3 **1470**

Output Coupling of Valve Generators for Industrial Heating Purposes.—Krüger. (*See* 1376.)

621.384.6 **1471**

A New Method for Particle Injection into Accelerators.—W. B. Jones, H. R. Kratz, J. L. Lawson, G. L. Ragan & H. G. Voorhies. (*Phys. Rev.*, 1st April 1950, Vol. 78, No. 1, pp. 60–62.) A method involving rapid damping of the radial or vertical oscillations for as large a number of revolutions as possible, and subsequent removal of this damping.

621.384.61 **1472**

The Electron Cyclotron.—P. A. Redhead, H. LeCaine & W. J. Henderson. (*Canad. J. Res.*, Jan. 1950, Vol. 28, Sec. A, No. 1, pp. 73–91.) A magnetic-resonance electron accelerator is described which is based on the principles suggested by Veksler (1913 and 2315 of 1945). A constant magnetic field and an accelerating r.f. field of frequency 2 800 Mc/s are used. Final energies of 5 MeV have been obtained in an experimental accelerator with a vacuum chamber of diameter 14 in.

621.384.611.2 **1473**

Validity of Two-Dimensional Design of Synchrotron Pole-Faces.—J. J. Wilkins. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362A, pp. 177–178.)

621.385.833 **1474**

Work carried out with the Magnetic Electron Microscope.—G. Dupouy. (*Rev. d'Optique*, Feb. 1950, Vol. 29, No. 2, pp. 89–100.)

621.385.833 **1475**

Proton Microscope Design. Application of Ion Optics in Mass Spectrography.—C. Magnan. (*Rev. d'Optique*, Feb. 1950, Vol. 29, No. 2, p. 100.) Summary only.

621.385.833 **1476**

Electron-Optics of Electrostatic Lenses. Comparison of Theoretical Resolving Powers of Electron and Proton Microscopes.—P. Chanson. (*Rev. d'Optique*, Feb. 1950, Vol. 29, No. 2, p. 111.) Summary only.

621.385.833 **1477**

Simple Expression for the Focal Length and Chromatic Aberration of an Extensive Group of Electrostatic Lenses.—É. Regenstreif. (*C. R. Acad. Sci., Paris*, 13th Feb. 1950, Vol. 230, No. 7, pp. 630–632.) See also 1213 of May.

621.385.833 : 530.12 **1478**

Electron Lenses in Relativistic Mechanics.—J. Laplume. (*Rev. d'Optique*, Feb. 1950, Vol. 29, No. 2, pp. 106–111.)

621.386.1 **1479**

Application of Electron Optics to X-Ray Tubes of Great Intensity.—S. Goldsztaub. (*Rev. d'Optique*, Feb. 1950, Vol. 29, No. 2, pp. 101–105.)

PROPAGATION OF WAVES

538.566.2 **1480**

Solution of a Transcendental Equation by means of Conformal Representation.—G. Eckart & T. Kahan. (*Rev. sci., Paris*, Dec. 1948, Vol. 86, No. 3300, pp. 723–726.) The equation considered, which occurs in wave-propagation theory, is

$$[\sqrt{(\lambda^2 - k_1^2)} - \sqrt{(\lambda^2 - k_2^2)}] \,/\, [\sqrt{(\lambda^2 - k_1^2)} + \sqrt{(\lambda^2 - k_2^2)}] = -\exp[+2ik\sqrt{(\lambda^2 - k_1^2)}]$$

where k_1^2, k_2^2 and k are real and positive and $k_1^2 > k_2^2$. By conformal transformation of the Riemann surface λ, the real positive roots of the equation are seen to lie on the real axis of λ in the interval $k_2 \leqslant \lambda < k_1$. Graphical methods are given for determining the values of the roots.

621.396.1 + 551.510.535] : 061.3 **1481**

Physical Society Conference [on the ionosphere] **at Cambridge, 14th to 16th July 1949.**—(*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, pp. 141–150.) Abstracts are given of 17 papers presented at the conference; these are all noted below in this section, or in the 'Geophysical and Extraterrestrial Phenomena' section.

621.396.11 + 62 : 396.81 **1482**

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

135. Calculation of Effective Phase, Group, and Pulse Velocities of Wave Propagation.—A. Fischler, G. H. Sloan & D. Goldenberg.
137. Radio Wave Propagation in a Curved Ionosphere.—J. M. Kelso.
153. A Microwave Propagation Test.—J. Z. Millar & L. A. Byam, Jr.

621.396.11 + 621.396.81 **1483**

Comparison of Measured and Calculated Microwave Signal Strengths, Phase, and Index of Refraction.—A. W. Straiton, A. H. LaGrone & H. W. Smith. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 45–48.) Experimental signal-strength/height curves and phase-change/height curves for 3.2-cm waves are compared with those derived from the corresponding curves showing the variation of the measured modified refractive index with height. The latter curves and attenuation factors determined from radio observations are also compared with the corresponding curves and attenuations deduced from meteorological observations. Four sets of radio data, for path lengths of 12.3, 31.6, 40 and 47 miles, are considered.

621.396.11 **1484**

The Speed of Radio Waves and its Importance in some Applications.—R. L. Smith-Rose. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 16–20.) 1949 I.R.E. National Convention paper reviewing present knowledge. The available data on the velocity of light are noted. Recent measurements of the velocity of 3-kMc/s radio waves in vacuo have given higher values than that for light, indicating an unresolved discrepancy. Investigations associated with navigation-aid systems have given values for radio wave velocities over land and sea paths. A table of mean velocity values, with estimated measurement accuracies, is given for both pulsed and c.w. radio transmissions at frequencies between 100 kc/s and 3.3 kMc/s.

621.396.11 **1485**

The Application of Ionospheric Data to Short-Wave Transmission Problems.—W. J. G. Beynon. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, p. 145.) Summary of Physical Society Summer Conference paper. "A short survey is presented of the fundamental theory underlying the application of normal-incidence ionospheric data to short-wave communication problems, with particular reference to calculating the maximum usable frequency (m.u.f.). Some aspects of the problem of applying normal-incidence data on ionospheric absorption to the calculation of field strength in long-distance transmission are also discussed."

621.396.11 **1486**

The Regular Behaviour of Long and Very Long Waves Returned from the Ionosphere.—J. A. Ratcliffe. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, p. 142.) Summary of Physical Society Summer Conference paper, defining the scope of the first session, indicating how the main contributions fit into the plan of the discussion and outlining some of the work carried out in Cambridge. The frequencies considered lie between 10 kc/s and 300 kc/s. Observations have mainly been near the frequencies of 16 kc/s (GBR, Rugby) and 100 kc/s (Decca), the academic workers generally concentrating on reflection effects at nearly vertical incidence, while commercial organizations have been mainly concerned with experiments at oblique incidence.

621.396.11 : 551.510.535 **1487**

Scattered Echoes Near the Critical Frequencies of the F_2 region.—R. Rivault. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, pp. 126–128. In French.) Physical Society Summer Conference paper. Two types are observed in vertical soundings at Poitiers, France: (a) when the scattering is not too diffuse, several components can be seen at frequency intervals of about $\frac{1}{4}$ or $\frac{1}{3}$ of the gyro-frequency. This type of scattering is most frequent during long nights and disappears at sunrise. It may be connected with the breakdown of the regular day-time stratification. (b) a G layer is sometimes in evidence as a diffuse pattern extending from about 3 Mc/s up to 5.2 Mc/s. it disappears near sunrise. Such scattering is associated with magnetic storms and meteor showers. Many photographic records are reproduced.

621.396.11 : 551.510.535 **1488**

Scattering of Radio Waves from Region E.—G. Millington. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, p. 149.) Summary of Physical Society Summer Conference paper. Sporadic echoes scattered directly back from the E layer show no definite correlation with visible meteors; it is suggested that they may be caused either by the sun or by the stars of the galaxy. Long-distance scattering, in which the sources are illuminated and the scattered signals received by reflection from the F layer, may be due to scattering centres in the E layer or on the ground. The risk of interference from an unwanted signal on a shared frequency as a result of long-distance scattering is discussed.

621.396.11 : 621.396.93 **1489**

The Characteristics of Low-Frequency Radio Waves Reflected from the Ionosphere, with particular reference to Radio Aids to Navigation.—C. Williams. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, pp. 143–144.) Summary of Physical Society Summer Conference paper. Observations at fixed and mobile (airborne) receiving points are used to determine changes of amplitude and phase in signals reflected by the E layer. From the results the relative amplitudes of ground and reflected waves are established as a function of distance from the transmitters, and the height of the reflecting layer and the reflection coefficient at oblique incidence during day and night are estimated.

621.396.11 : 621.396.93 **1490**

The Effects of Sky-Wave on the Planning of Navigational Aids using Frequencies in the 70–130-kc/s Band.—W. T. Sanderson. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, p.143.) Summary of Physical Society Summer Conference paper. The accuracy of the Decca system depends on the stability of the phase-locked transmissions and observations have been made to determine the phase variation which can be expected at various ranges and times. Results indicate that in English latitudes the night sky wave effects persist throughout the day during mid-winter on 70 kc/s, falling to about half the night value at 120 kc/s. During the summer daylight (April–September) the effects are so small up to 300 miles that they are difficult to measure. Hawker has found that the secant of the sun's zenithal distance at noon gives a good approximation to the relative amplitude of the daylight errors throughout the year. The bearing of these results on the planning of medium-range c.w. navigation aids is discussed.

621.396.11.029.45 + 621.396.81.029.45 **1491**

The Ground Interference Pattern of Very-Low-Frequency Radio Waves.—K. Weekes. (*Proc. Instn elect. Engrs*, Part III, March 1950, Vol. 97, No. 46, pp. 100–107.) Measurements in an aircraft of the strength of 16-kc/s signals at distances up to 850 km from the transmitter are described. At distances up to 300 km the results agree with those of previous experiments by Budden, Ratcliffe & Wilkes (3441 of 1939). The ionospheric reflection conditions which would account for these results are found to be no longer valid at the greater distances, and there appears to be a considerable change in these conditions at about 400 km. This applies to reflection coefficient, equivalent height (or phase change at reflection) and also polarization, which becomes approximately linear at 500 km.

621.396.11.029.58/.64 **1492**

Propagation of Short Radio Waves over Desert Terrain.—J. P. Day & L. G. Trolese. (*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 165–175.) The vertical distribution of field over a 190-ft interval was measured during daytime, when the atmosphere was well mixed, and at night, when a small-scale duct was formed, over an optical 26.7-mile path and a non-optical 46.3-mile path on various frequencies between 25 and 24 000 Mc/s. Transmitters and receivers were fitted in elevator cabs in 200-ft towers. The results are discussed and correlated with simultaneous meteorological measurements. Diffraction and partial-reflection effects were also studied. With frequencies up to 1 000 Mc/s the duct affects the magnitude but not the shape of the height/gain curves; with microwaves the shape is altered considerably.

621.396.11.029.58 : 621.396.93 **1493**

Very-Low-Frequency Propagation.—S. B. Smith & K. W. Tremellen. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, p.143.) Short summary of Physical Society Summer Conference paper. Earlier experiments

during 1920–1926 are discussed, with particular reference to (*a*) apparent abnormalities and other little known phenomena, (*b*) world atmospheric noise centres, seasonal and diurnal variations in direction and intensity, (*c*) d.f. using different techniques, with special reference to reception along various geomagnetic paths.

621.396.81 **1494**

On the Deduction of the Refractive Index Profile of a Stratified Atmosphere from Radio Field-Strength Measurements.—J. W. Green. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 80–88.) A method due to Macfarlane (2894 of 1947) derives the refractive index profile from the variations of received amplitude with height and range. Application to amplitudes calculated from standard diffraction theory and duct propagation theory confirmed the formal accuracy of the method, but suggested that it would be very sensitive to small measurement errors. Application to field-strength values observed over water and land for standard and non-standard atmospheric conditions confirmed this and showed that the formula was unsatisfactory except in a limited frequency range under standard conditions.

621.396.81 : 551.510.535 **1495**

Measurements on Long and Very Long Waves.—R. N. Bracewell. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, p.144.) Summary of Physical Society Summer Conference paper. Details are given of the regular daily and seasonal variations of waves of frequencies 16 kc/s and 100 kc/s observed, after reflection from the ionosphere, at distances of 90, 200 and 500 km. The night reflection coefficient for a 16-kc/s wave is found to be about 0.5 in all seasons; that for 70- and 113-kc/s waves is markedly lower, and decreases in summer. From round about sunrise the reflection coefficient for the 16-kc/s wave drops in summer, but not in winter; for the 70- and 113-kc/s waves the fall occurs both in summer and winter, though that in summer is far more marked. The reflection height, about 90 km at night in all seasons, exhibits corresponding decreases. Polarization conditions are also noted. When observations are made at a distance of 500 km from the transmitter, multiple reflections are important, and the sunrise variations are more rapid.

621.396.81.029.6 **1496**

Radio Propagation Variations at V.H.F. and U.H.F.—K. Bullington. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 27–32.) 1949 I.R.E. National Convention paper. Long-period observations of field-strength variation as a function of distance from the transmitter, of fading effects and of the influence of irregular terrain, buildings and trees are analysed and checked against theory where possible. Using median values together with a measure of the spread of values for fading and shadow losses, empirical formulae are obtained for the service area of and distance required between co-channel stations for any assigned ratio of signal to interference.

621.396.812.3 **1497**

The Variations in Direction of Arrival of High-Frequency Radio Waves.—W. Ross. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, pp. 149–150.) Summary of Physical Society Summer Conference paper. Bearings observed on h.f. transmissions are subject to continuous fluctuations, apart from those due to variable instrument errors. Both rapid and slow fluctuations occur, the latter with periods from a few minutes up to half an hour. These slow fluctuations are similar for bearings on neighbouring frequencies and transmission paths; they are apparently due to fairly localized tilting of the ionosphere layers. The rapid fluctuations are observed even when pulses are used, and hence may be caused by ionosphere irregularities of smaller scale than those causing slow fluctuations. The random irregularities may be due to the spreading of disturbances produced by perturbations in the regular diurnal changes in the ionosphere. See also 3424 of 1949 (Ross & Bramley).

621.396.812.3 **1498**

Some Work at Cambridge on Radio Fade-Outs.—K. Weekes. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, pp. 146–147.) Summary of Physical Society Summer Conference paper. Observations on the changes of 'phase path' and amplitude of the pulse reflected from the E region during fade-out were made (*a*) at vertical incidence on 2.0 and 2.4 Mc/s, (*b*) near vertical incidence on 70 and 113 kc/s, and (*c*) near vertical incidence on 16 kc/s and 40 kc/s. The 'phase path' may decrease initially by 2 to 4 km in case (*a*), and by as much as 20 km in cases (*b*) and (*c*); the amplitude decreases initially by a factor which is at least 200 in case (*b*), but is only of the order of 3 in case (*c*). There is rapid recovery to normal values as the fade-out ends. An ionization distribution which would account for the observed results is suggested.

621.396.812.3 : 523.72 **1499**

Sudden Enhancements [of atmospherics] **on Very Long Waves.**—R. Bureau. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362B, pp. 122–126. In French.) Physical Society Summer Conference paper. The increased level of atmospherics received on wavelengths of 11 000 m during a solar flare is usually accompanied by a Dellinger fade-out on short-wave circuits. Several instances have been found where the fade-out is preceded by an apparent short increase in recorded field-strength, which may be caused by the reception of solar radiation for a few seconds before it is absorbed by the increased ionization in the D region. Many photographic records are reproduced.

621.396.812.3 : 523.74 **1500**

Unusual Ionospheric Storm.—T. W. Bennington. (*Wireless World*, April 1950, Vol. 56, No. 4, pp. 131–132.) A giant sunspot crossing the sun's meridian on 20th Feb. 1950 was associated not only with the usual phenomena of an ionospheric storm, but with strong reception in Great Britain of transmissions from Leningrad and Stockholm in the 6-m band, and by very rapid fading of the medium-wave London Home Service transmission. The first phenomenon is probably due to the 'auroral' type of sporadic E and the second to exceptional turbulence of the F layer.

RECEPTION

621.396.621 **1501**

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

13. Considerations in Low Noise Figure Microwave Receiver Design.—M. T. Lebenbaum & P. D. Strum.
66. Highly Selective Mobile Receiver.—R. T. Adams, R. A. Felsenheld & G. W. Sellers.
107. Frequency-Modulation Interference.—L. B. Arguimbau.
108. The Theory of Amplitude-Modulation Rejection in the Ratio Detector.—B. D. Loughlin.
109. An Improved Method of Frequency Conversion.—V. H. Aske & J. Grund.
110. Common-Frequency Carrier-Shift Radio-Teletype Converter.—R. R. Turner.
136. An Atmospheric Waveform Receiver.—W. J. Kessler & S. E. Smith.
154. Diversity Reception Techniques.—S. H. Van Wambeck & A. H. Ross.
155. Experimental Evaluation of Diversity Receiving Systems.—J. L. Glaser & S. H. Van Wambeck.

1502

621.396.611 : 537.228.1 : 548.0

Piezoelectric Crystals in Receiver Construction.—F. C. Saic. (*Elektrotech. u. Maschinenb.*, Feb. 1950, Vol. 67, No. 2, pp. 44–50.) A brief review of the characteristics of piezoelectric crystals and a discussion, illustrated by reactance diagrams, of their application in the i.f. stage of wideband radio receivers.

1503

621.396.61 : 621.396.619.11/.13

Signal-to-Thermal Noise Ratio.—M. V. Callendar. (*Wireless Engr*, March 1950, Vol. 27, No. 318, pp. 96–100.) Curves are given of output signal/thermal-noise ratio for a f.m. receiver. The signal/noise ratios range from very large values to values <1. Corresponding curves are also given for an a.m. receiver, and a comparison is made, emphasizing the effect of the ratio of pre-detector to post-detector bandwidth in each case. F.m. can give results at least equal to a.m. in respect of signal/noise ratio for communication work, provided that the pre-detector bandwidth is no greater than is necessary to accept the full deviation, and that the limiter is fully efficient: the deviation ratio for such work should not exceed a value of about 4. In practice, an a.m. receiver will in some instances give a slightly better result than a corresponding f.m. receiver, particularly if any slight mistuning is present.

1504

621.396.621 : 621.396.822

Design Factors in Low-Noise-Figure Input Circuits.—M. T. Lebenbaum. (*Proc. Inst. Radio Engrs*, Jan. 1950, Vol. 38, No. 1, pp. 75–80.) 1948 I.R.E. National Convention paper. A method is described for calculating the minimum noise figure attainable by the use of double-tuned circuits in the inputs of h.f. amplifiers: this provides simple data for designing the network. For active and passive valve input loading a graphical method is given for determining the constants of a double-tuned input circuit with minimum noise figure.

1505

621.396.621.54

The Diode as a Mixing Device in the U.H.F. Band.—H. F. Mataré. (*Elektron Wiss. Tech.*, Feb. 1950, Vol. 4, No. 2, pp. 48–52.) Analysis indicating the conditions under which the large reactive effect of a diode mixer may be used to advantage.

1506

621.396.621.54 : 621.396.828

Elimination of Radio Interference by Off-Frequency Inversion.—S. Freedman. (*Radio & Televis. News*, March 1950, Vol. 43, No. 3, pp. 53–57, 154.) Circuit description and performance details of the Type-MCL-4 signal splitter. Crystal oscillators operating respectively on frequencies 50 kc/s above and below the receiver i.f. frequency, and an asymmetrical high-pass filter, with cut-off frequency 50 kc/s, permit selection of the sideband giving greatest interference attenuation and give high selectivity. A further 1-kc/s heterodyne and filter give additional selectivity for c.w. reception. See also 811 of 1948 (McLaughlin).

1507

621.396.822

Induced Grid Noise and Noise Factor.—R. L. Bell. (*Nature, Lond.*, 18th March 1950, Vol. 165, No. 4194, pp. 443–444.) Assuming that all the induced grid noise is correlated with cathode/anode shot noise, the minimum noise factor obtained on adjusting conductive and susceptive components of grid-ground admittance is independent of lead inductance effects, space-charge capacitance, transit-time damping and induced grid noise itself. In this hypothetical case, the optimum detuning at the grid required for minimum noise factor is very nearly equal to the space-charge capacitance.

1508

621.396.828

The Main Principles of the Protection of Radio Receivers against Interference due to H.F. Oscillators for Induction Heating.—F. E. Il'gekit & K. V. Bazhenov. (*Radiotekhnika, Moscow*, Nov./Dec. 1949, Vol. 4, No. 6, pp. 14–23. In Russian.)

1509

621.396/.397].828 : 621.327.43

Interference from Fluorescent Tubes.—"Diallist". (*Wireless World*, March 1950, Vol. 56, No. 3, pp. 93–94.) Production of r.f. oscillations in fluorescent tubes is investigated and a possible explanation given. Suppression of these oscillations is discussed and a suitable practical method described.

1510

621.397.828

Interference from Television Receivers.—M. G. Scroggie. (*Wireless World*, April 1950, Vol. 56, No. 4, pp. 126–129.) The line-scanning system of a television receiver is a source of magnetic and electric interference fields. Modern trends in design tend to decrease the magnetic but increase the electric field. The magnetic field chiefly affects portable receivers, but these can fortunately be moved out of the interference region. The electric field can be substantially decreased by the use of simple screening in the television receiver.

STATIONS AND COMMUNICATION SYSTEMS

1511

621.39

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

15. Speech Transmission through Restricted Bandwidth Channels.—M. J. DiToro, W. Graham & S. Schreiner.
16. Application of Communication Theory to Periodic Radio Systems.—M. Leifer & N. Marchand.
17. Some Aspects of Data Transmission over Narrow-Band Communication Circuits.—M. M. Brenner.
31. Transient Response of Asymmetrical Carrier Systems.—G. M. Anderson & E. M. Williams.
37. Signal Corps High-Frequency Radio Communication Research and Development.—J. Hessel & H. F. Meyer.
38. Military Single-Sideband Equipment Development.—R. A. Kulinyi.
39. Radio Relay Design Data, 60 to 600 Mc/s.—R. Guenther.
40. Multiplex Microwave Radio Relay.—D. D. Grieg & A. M. Levine.
41. Cross Talk in Frequency- and Phase-Modulated Radio Relays used in Conjunction with Multichannel Telephony Equipment.—S. Fast.
62. Product Phase Modulation and Demodulation.—D. B. Harris & D. O. McCoy.
63. Some Novel Methods for the Generation of P.C.M.—N. R. Castellini, D. L. Jacoby & B. Keigher.
65. Techniques for Closer Channel Spacing at V.H.F. and Higher Frequencies.—C. F. Hobbs & W. B. Bishop.
110. Common-Frequency Carrier-Shift Radio-Teletype Converter.—R. R. Turner.
156. Comparison of Modulation Methods for Voice Communication over Ionospheric Radio Circuits.—M. G. Crosby, H. F. Meyer & A. H. Ross.
157. Comparison of Modulation Methods for Facsimile Communication over Ionospheric Radio Circuits.—M. Acker & B. Goldberg.

1512

621.39.001.11

Communication in the Presence of Noise — Probability of Error for Two Encoding Schemes.—S. O. Rice. (*Bell Syst. tech. J.*, Jan. 1950, Vol. 29, No. 1, pp. 60–93.) "Recent work by C. E. Shannon and others has led to an expression for the maximum rate at which information can be transmitted in the presence of random

noise. Here two encoding schemes are described in which the ideal rate is approached when the signal length is increased. Both schemes are based upon drawing random numbers *from* a normal universe, an idea suggested by Shannon's observation that in an efficient encoding system the typical signal will resemble random noise. In choosing these schemes two requirements were kept in mind: (1) the ideal rate must be approached, and (2) the problem of computing the probability of error must be tractable."

621.39.001.11 **1513**

Calculation of Transmission Efficiency according to Hartley's Definition of Information Content.—A. G. Clavier. (*Ann. Télécommun.*, Jan. 1950, Vol. 5, No. 1, pp. 29–34.) French version of 2045 of 1949 correlated with 1241 of May (Aigrain).

621.391.63 **1514**

Comparative Study of the Propagation of Optical Radiations of Different Wavelengths in the Atmosphere.—G. Goebel. (*Fernmeldetech. Z.*, Feb. 1950, Vol. 3, No. 2, pp. 43–47.) Measurements were made of the received intensity of a light signal modulated at 1 kc/s and transmitted over a 3.2-km path, under different atmospheric conditions. No general inferiority of short waves to long waves was observed. Air movements and humidity variations had no measurable effect; warm air layers in the propagation path caused a 1–50-c/s short-duration scatter. Storms affected propagation only when accompanied by rain or electric discharges. No clearly defined parameters for distance attenuation were found. High ground-temperature caused short-term fading, while smoke and mist caused selective fading. Even in cloudy conditions the ratio of the received intensities of ultra-violet and deep-red did not exceed 10^2, so that with a receiving amplifier compensated for fading a sufficiently constant signal level should be ensured for communication over the whole optical range.

621.396.5 **1515**

Ten Years of Radio-Telephone Communications with Mountain Stations.—P. Hãni. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, 1st March 1950, Vol. 28, No. 3, pp. 112–121. In German and French.) A short account of developments since 1933–1936, when the first R/T links were installed, together with a description of the equipment now in use. The central transmitter gives about 4-W output at 57 to 75 Mc/s. The installation is mains operated and incorporates an automatic calling system by which the subscriber can call any station on the central network. Output from subscriber stations, which are battery operated, is 0.3 W at a frequency adjustable from 40 to 60 Mc/s.

621.396.619.13 : 621.396.41 **1516**

The Application of Frequency Modulatiop to V.H.F. Multi-Channel Radiotelephony.—J. H. H. Merriman & R. W. White. (*Proc. Instn elect. Engrs*, Part III, March 1950, Vol. 97, No. 46, pp. 123–124.) Discussion on 3513 of 1948.

621.396.619.16 **1517**

Pulse Communication.—A. Bloch: E. Fitch. (*Proc. Instn elect. Engrs*, Part III, March 1950, Vol. 97, No. 46, p. 107.) Comment on 2079 of 1948 (Cooke; Jelonek & Fitch; Oxford) and 2619 of 1948 (Fitch), pointing out the essential equivalence of the method described by Fitch of deriving the spectrum of a pulse transmission and the method previously given by Bloch.

621.396.619.16 **1518**

The Optimum Pulse-Shape for Pulse Communication.—J. H. H. Chalk. (*Proc. Instn elect. Engrs*, Part III, March 1950, Vol. 97, No. 46, pp. 88–92.) The optimum pulse shape is determined for minimum adjacent-channel interference. The method is also applied to find the pulse shape making the energy available for detection a maximum for a receiver with a given pass band. In either case the optimum pulse shape depends only on the product of pulse length and bandwidth.

621.396.619.16 **1519**

Pulse Code Modulation.—D. G. Holloway. (*Electrician*, 3rd & 10th March 1950, Vol. 144, Nos. 3742 & 3743, pp. 679–683 & 763–765.) An outline of fundamental theory.

621.396.619.24 : 621.396.828 **1520**

Folded-Sideband Modulation.—J. L. A. McLaughlin. (*Electronics*, March 1950, Vol. 23, No. 3, pp. 88–91.) The basic principles are described of a system in which bands of frequencies several kilocycles wide are transmitted sequentially in a narrow band on one side of a carrier. The width of the frequency spectrum used is less than the information bandwidth. Interfering beat notes produced by unwanted carriers falling within the sideband used are eliminated by shifting them to the other side of the carrier. See also 1782 of 1949.

621.396.65 **1521**

Résumé of V.H.F. Point-to-Point Communication.—F. Hollinghurst & C. W. Sowton. (*Proc. Instn elect. Engrs*, Part III, March 1950, Vol. 97, No. 46, pp. 121–123.) Discussion on 2080 of 1948.

621.396.65 : 621.396.5 **1522**

Multiplex Telephony Systems and Radio Links.—J. P. Voge. (*Ann. Télécommun.*, Feb. & March 1950, Vol. 5, Nos. 2 & 3, pp. 73–88 & 90–97.) Analysis of modulation methods and comparison of different multiplex systems. Factors considered are number of channels available, signal/noise ratio, power and bandwidth required, reliability and secrecy. Characteristics of recently constructed radio multiplex systems are given, including two systems in use in the United States for communicating television programmes.

621.396.65 : 621.397.5 **1523**

A Microwave System for Television Relaying.—J. Z. Millar & W. B. Sullinger. (*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 125–129.) I.R.E. 1949 National Convention paper. Requirements for television radio relay links are discussed and a Philco system is described. This operates in the 6-kMc/s common-carrier band and uses heterodyne modulation with a klystron, Type SAC-19, developed by the Sperry Corporation specially for this application. The equipment has been installed by Western Union for transmission between New York and Philadelphia. Photographs show the repeater, the type of aerial used, and a square-wave signal and C.B.S. test pattern after transmission from one terminal to the other and back again. See also 1185 of 1949 (Forster).

621.396.712 **1524**

The National Transmitter at Beromünster with Unmodulated Aerial Power of 100–200 kW.—H. Affolter. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, 1st March 1950, Vol. 28, No. 3, pp. 95–104. In German.) Illustrated description of the new transmitter and the general layout, showing particularly the h.v. and rectifier equipment with simple switching arrangements for supplying either the old or the new transmitter, the water-cooling system and the special tubular h.f. feeder line. The installation incorporates the latest ideas in high-power transmitter design. Performance figures are tabulated. Frequency range is 520–1 580 kc/s; overall efficiency at maximum power and 100% modulation is 40.8%.

621.396.931 1525

Small-Town Mobile F.M. Operation.—E. Cook. (*Tele-Tech*, Feb. 1950, Vol. 9, No. 2, pp. 26–28, 55.) Circuit details are given of a two-way R/T installation operating on 37.74 Mc/s. All receivers are tuned to a common frequency and their a.f. stages are biased to cut-off until a signal is received. An individual receiver responds when the carrier of the calling transmitter is modulated by a particular tone.

SUBSIDIARY APPARATUS

621.396 + 621.316.722 1526

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

70. Modern Methods of Servo Synthesis.—R. McCoy & D. Herr.
114. High-Voltage Regulation by means of Corona Discharge between Coaxial Cylinders.—S. W. Lichtman.
165. Universal Precision Resolvers.—D. L. Herr.

621.3.027.3 : 621.3.032.4 1527

Heating the Filaments of Valves in a Cascade Generator by means of High-Frequency Current.—T. Douma & H. P. J. Brekoo. (*Philips tech. Rev.*, Oct. 1949, Vol. 11, No. 4, pp. 123–128.) Considerable simplification of the h.t. filament-heating circuits is made possible by the use of filament-current transformers with ferroxcube cores.

621.314.63 1528

Characteristics of Compound Barrier-Layer Rectifiers.—E. Billig & P. T. Landsberg. (*Proc. phys. Soc.*, 1st Feb. 1950, Vol. 63, No. 362A, pp. 101–111.) "The assumptions involved in Mott's and Schottky's theories of rectification are analysed and a potential barrier at the metal-semiconductor interface is proposed which enables one to pass continuously from one theory to the other."

621.316.721.076.7 1529

An Electronic Current Regulator.—N. F. Verster. (*Appl. sci. Res.*, 1950, Vol. B1, No. 5, pp. 358–362.) A method for stabilizing the magnet current of a β-ray spectrometer, derived from a 20-kW d.c. generator. A vibrating-contact d.c. amplifier is used to amplify the error voltage and control the field of an exciting generator which energizes the fields of the main generator. Stabilization is within 0.1% throughout the range 2–420 A.

621.316.722.1 1530

Design of a Voltage-Stabilizing Circuit with the Regulating Valve connected in Parallel.—K. B. Mazel'. (*Radiotekhnika, Moscow*, Nov./Dec. 1949, Vol. 4, No. 6, pp. 74–79. In Russian.)

621.316.73 1531

A Magnetic Field Stabilization Circuit.—L. Katz, P. A. Forsyth, L. F. Cudney, G. W. Williams, H. E. Johns & R. N. H. Haslam. (*Canad. J. Res.*, Jan. 1950, Vol. 28, Sec. A., No. 1, pp. 67–72.) A rotating coil in the air gap of a large electromagnet generates an alternating voltage proportional to the field strength. A fraction of this voltage is balanced against a reference voltage derived from a similar coil rotating between the poles of a permanent magnet. Departures from balance are used to control the current supplied to the electromagnet so as to maintain a steady field. By varying the fraction used for balance, the field may be controlled at any value within a wide range.

621.396.682 1532

Stabilized Anode Supply Unit using Mazda-2050 Thyratrons.—L. Chrétien. (*T.S.F. pour Tous*, Feb. 1950, Vol. 26, No. 256, pp. 53–58.) A simple circuit including two thyratrons and also two Type-VR150 stabilizing tubes. The voltage change is about 3% for load variation from 50 mA to 300 mA or supply-voltage variation from 80 V to 160 V.

TELEVISION AND PHOTOTELEGRAPHY

621.396.[97].828 : 621.327.43 1533

Interference from Fluorescent Tubes.—"Diallist". (*See* 1509.)

621.397.5 1534

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

26. Specification for Quality of the Visual Output of Picture Tube Screens.—A. E. Martin.
27. The Importance of Practical Design and Specifications for Effective Production and High Quality.—J. Manuele.
47. 5-kW Visual and 2.5-kW Aural Television Amplifiers.—P. Breen.
48. Design Considerations in TV Transmitters.—L. Pollack, E. Bradburd & I. Krause.
49. Wideband R.F. Problems in Television Transmitters.—E. Bradburd & L. Pollack.
50. The Vidicon—A New Photoconductive Television Pickup Tube.—P. K. Weimer, S. V. Forgue & R. R. Goodrich.
51. Industrial Television System.—R. C. Webb & J. M. Morgan.
56. Filters for Television Interference.—A. M. Seybold.
78. A 1-kW U.H.F. Television Transmitter.—T. M. Gluyas.
79. A Supergain U.H.F. Television Transmitting Antenna.—O. O. Fiet.
80. Design of a Hybrid Ring Diplexer for Ultra-High-Frequency Television Use.—W. H. Sayer & J. M. De Bell, Jr.
81. Construction and Operation of an Experimental U.H.F. Television Station.—R. F. Guy & F. W. Smith.
82. Electro-Optical Filters for Color Television.—V. A. Babits & F. Hicks, Jr.
102. Use of Miniature Pentode RCA-6CB6 in Television Intermediate-Frequency Amplifiers.—W. E. Babcock.
103. Noise Suicide Circuit.—H. E. Beste & G. D. Hulst.
104. Quality Rating of Television Images.—P. Mertz, A. D. Fowler & H. N. Christopher.
105. Television Image Reproduction by use of Velocity-Modulation Principles.—M. A. Honnell & M. D. Prince.
106. Design of Printed-Circuit Television Tuner.—D. Mackey & E. J. Sass.

621.397.5 1535

Colour Television in the U.S.A.—Comparison of Different Methods.—L. Chrétien. (*T.S.F. pour Tous*, March 1950, Vol. 26, No. 257, pp. 108–111.) Critical review of different systems, based on an article in *Electronics*, Dec. 1949, entitled "New Directions in Colour Television". See 763 of March (D.G.F.).

621.397.5 : 621.396.65 1536

A Microwave System for Television Relaying.—Millar & Sullinger. (*See* 1523.)

621.397.5 (083.74) 1537

Report on the International Television Standards Conference.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, p. 116.) Extracted from a report by D. G. Fink on the C.C.I.R. conference at Zürich, July 1949. National attitudes on television standards are reviewed and conference conclusions and questions for further study are noted.

621.397.5(023.74)

1538

Television Standards.—Y. Delbord. (*Ann. Télécommun.*, Nov. & Dec. 1949, Vol. 4, Nos. 11 & 12, pp. 388–396 & 425–429; Jan. & Feb. 1950, Vol. 5, Nos. 1 & 2, pp. 35–47 & 50–56.) In four parts: (*a*) historical review of the development of the various standards, including a comprehensive chart showing the systems adopted in different countries; (*b*) relative importance of the different standards; (*c*) reasons for international divergence; (*d*) the French point of view.

621.397.9

1539

New Television Equipment at Alexandra Palace.—(*Engineer, London*, 3rd Feb. 1950, Vol. 189, No. 4906, pp. 146–147.) General description of (*a*) film-dubbing suite for the production of newsreels and other films to which the sound track is added after filming; (*b*) telefilm recording room where television programmes are recorded on cinematograph film; (*c*) central room where films are televised for transmission in the programme; (*d*) the accommodation and proposed development of the television studio centre at Lime Grove, Shepherds Bush, London.

621.397.61

1540

The New Eiffel Tower [television] **Sound Transmitter.**—L. Thourel. (*Electronique, Paris*, March 1950, No. 40, pp. 27–31.) Description of the circuits and constructional features of the r.f. amplifier chain which delivers 5-kW useful carrier power at 42 Mc/s. It comprises three units housed in one case. The 7-Mc/s crystal-oscillator drive unit and the first amplifier/frequency-multiplier unit are removable; the main amplifier and power stages are built in. The anodes of the valves in the final stage are water-cooled. Efficiency of this stage is 54% with anode voltage 5.4 kV.

621.397.62

1541

Television Spot-Wobble.—R. W. Hallows. (*Wireless World*, March 1950, Vol. 56, No. 3, pp. 84–86.) Discussion of a method of eliminating the horizontal lines usually seen in a television picture, by giving the spot a rapid vertical oscillation of small amplitude so as not to overlap to any large extent the boundaries of a single scanning line. A slight loss of vertical definition results.

621.397.62

1542

Selectivity in Television.—W. T. C. (*Wireless Engr*, March 1950, Vol. 27, No. 318, pp. 69–71.) Selectivity is discussed in relation to television reception in Britain, the main problem being to prevent the sound signal from interfering with the picture signal. This is particularly difficult when, as in the Midlands transmission, only the lower of the vision sidebands, which lies between the vision and sound carriers, is transmitted. The merits of tuned-r.f. and superheterodyne receivers are compared. The choice between the two depends on whether or not it is feasible to obtain rejector circuits of sufficiently high Q at signal frequency, the important factor being the relation of the product of bandwidth and circuit Q to signal frequency.

621.397.62 : 621.385.2 : 621.315.59

1543

Application of Germanium Diodes in Veryhigh and Ultrahigh TV Sets.—J. H. Sweeney. (*TV Engng, N.Y.*, Feb. 1950, Vol. 1, No. 2, pp. 10–11, 36.) Discussion of the relative merits of the crystal diode as a replacement for the valve diode, particularly in video-detector, d.c.-restorer and a.f. discriminator circuits.

621.397.81

1544

Fringe-Area Television.—(*Wireless World*, March & April 1950, Vol. 56, Nos. 3 & 4, pp. 87 & 139.) Two maps show values of the video field-strength recorded with mobile equipment at many places about 70 miles from the Sutton Coldfield transmitter. The greatest variations observed were, as might be expected, in the hilly country of Wales.

621.397.813 : 621.397.62

1545

The Distortion of Video and Audio Signals in a Television Receiver.—G. I. Bvalik. (*Radiotekhnika, Moscow*, Nov./Dec. 1949, Vol. 4, No. 6, pp. 34–46. In Russian.) The use of a single receiving channel for a.m. video signals and f.m. audio signals is limited by the presence of the nonlinear element, the detector, which causes intermodulation distortion. A mathematical analysis of this effect on the quality of the image and the sound is presented and suggestions are made for rendering the distortion of the audio signals negligible and reducing that of the video signals to a few per cent. It is shown by this analysis and also by experiments that a second i.f. amplifier is not required for the sound channel.

621.397.82 : 621.392.52

1546

Eliminating TVI with Low-Pass Filters.—Grammer. (*See* 1367.)

621.397.828

1547

Television Interference Suppression.—L. Varney. (*R.S.G.B. Bull.*, March 1950, Vol. 25, No. 9, pp. 290–294.) Synopsis of a paper read at a meeting of the Radio Society, Oct. 1949. Achievements in this field are reviewed and some recent improvements in technique are described. See also 2336 of 1949.

621.397.62

1548

The Principles of Television Reception. [Book Review]—A. W. Keen. Publishers: Pitman & Sons, London, 319 pp., 30s. (*Wireless Engr*, March 1950, Vol. 27, No. 318, pp. 94–95.) "The book can be recommended for those who have little or no knowledge of television but who have a good background of ordinary wireless theory and practice. It will enable them to obtain a good general, but hardly a detailed, knowledge of television."

TRANSMISSION

621.3.016.35 : 621.396.61

1549

Static and Dynamic Temperature Compensation of Transmitters.—E. Roske. (*Fernmeldetech. Z.*, Feb. 1950, Vol. 3, No. 2, pp. 53–61.) Discussion of the effect of temperature change on frequency stability and the possibilities of compensation by the use of ceramic components.

621.316.726 : 621.396.615

1550

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) A summary is given of the following paper:

111. A Simple Crystal Discriminator for F.M. Oscillator Stabilization.—J. Ruston.

621.396.61.029.58

1551

Continuously-Tuned 50-kW Transmitter.—J. L. Hollis. (*Electronics*, March 1950, Vol. 23, No. 3, pp. 70–73.) Circuit and construction details of the U.S. Navy transmitter Type AN/FRT-5 and AN/FRT-6. Motor-driven, servo-positioned units are used to tune individual stages and allow operation on any frequency from 4 to 26 Mc/s without tuned-circuit switching. Frequency changing is effected in less than two minutes.

621.396.619.23

1552

Non-Linear Effects in Rectifier Modulators.—D. G. Tucker & E. Jeynes. (*Wireless Engr*, Feb. 1950, Vol. 27, No. 317, p. 66.) Comment on 2184 of 1949 (Belevitch).

621.397.61

1553

The New Eiffel Tower [television] **Sound Transmitter.**—Thourel. (*See* 1540.)

VALVES AND THERMIONICS

1554

621.385.5 : 621.396.615.14

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

10. Glass-Sealed Germanium Diodes.—S. F. Amico.
11. High-Temperature Characteristics of Germanium Diodes.—L. S. Pelfrey.
19. Accelerated Life Testing of Vacuum Tubes.—J. Rothstein.
87. A New Class of Switching Tubes for Digital Applications.—J. Katz.
89. A New Type of Frequency-Control Tube.—R. W. Slinkman.
90. M.I.T. Electrostatic Storage Tube.—S. H. Dodd, H. Klemperer & P. Youtz.
91. Performance and Analysis of a Transverse Current Travelling-Wave Amplifier and Limiter.—L. M. Field.
92. An Experimental Electron Tube using Space-Charge Deflection of the Electron Beam.—J. T. Wallmark.
112. A New 'Soft Structure' for Rugged Receiving Tubes to Improve Resistance to Shock and Electron Emission.—G. W. Baker.
113. Hydrostatic Pressure in an Electron Gas: its Application to Electron-Beam/Electromagnetic-Wave Interaction.—P. Parzen & L. Goldstein.
115. Thyratron Grid Emission and the Trigger-Grid Thyratron.—L. Malter & M. R. Boyd.
116. High-Intensity Pulse-Distribution Tube.—P. M. G. Toulon.
138. Development of 10-cm High-Power Pulsed Klystron.—M. Chodorow, E. L. Ginzton, I. Neilsen & S. Sonkin.
139. Space-Charge Effects in Reflex Klystrons.—V. Westberg & M. Chodorow.
140. Recent Development in High-Power Klystron Amplifiers.—C. Veronda & V. Learned.
141. A New Super-Power Beam Triode.—W. N. Parker, W. E. Harbaugh, M. V. Hoover & L. P. Garner.
142. External-Cathode Inverted Magnetron.—J. F. Hull.
158. A Vacuum Seal between Metals and Ceramics for High Temperature Applications.—H. W. Soderstrom & K. H. McPhee.
159. Effect of Coating Composition of Oxide-Coated Cathodes on Electron Emission.—E. G. Widell & R. A. Hellar.
160. Effects of Controlled Impurities in Nickel Core Metal on Thermionic Emission from Oxide-Coated Cathodes.—G. Hees.
161. Investigation of Contaminant in Vacuum Tubes.—P. D. Williams.
162. Hot-Strength Properties of Filamentary Alloys.—B. Wolk.

1555

621.385.029.63/.64 : 537.291 + 538.691

Electron Beams in Axially Symmetrical Electric and Magnetic Fields.—Wang. (*See* 1395.)

1556

621.385.15

A New Secondary Cathode.—C. S. Bull & A. H. Atherton. (*Proc. Instn elect. Engrs*, Part III, March 1950, Vol. 97, No. 46, pp. 65–71.) The emission from the secondary cathode in a multiplier stage gradually decreases during its life; this is due to bombardment by the primary electron beam, which causes disintegration of the surface oxide layer and gradual exposure of the clean base metal of the secondary cathode. To avoid this, thicker coatings of MgO were tried but had too high a resistance. A new type of cathode, made from a mixture of MgO and $BaCO_3$, was found to be sufficiently conducting, and gave a secondary emission ratio of about 3. The emission remained sensibly constant for over 1 000 hours, with an operating temperature of 400°C and a primary bombarding current density of 20 mA/cm². The use of this cathode has made possible the development of an orbital-beam single-stage thermionic multiplier valve with a mutual conductance of 20 mA/volt and input capacitance of 8 pF.

1557

621.396.615.141.2

The Behaviour of Multiple-Circuit Magnetrons in the Neighbourhood of the Critical Anode Voltage.—W. E. Willshaw & R. G. Robertshaw. (*Proc. phys. Soc.*, 1st Jan. 1950, Vol. 63, No. 361B, pp. 41–45.) The mechanism of operation of the multiple-circuit magnetron oscillator in the region of minimum magnetic field and voltage, where the efficiency is commonly assumed to approach zero, should approach that of an oscillator of the travelling-wave-valve type, providing that a cathode of suitable size is used. Useful efficiencies should thus be obtainable under these conditions. Details of experiments are given in which an electronic efficiency of 12% was obtained at a wavelength of 3 cm at values of magnetic field and voltage several times lower than those used for high-efficiency operation. The mode of operation was determined by the value of the magnetic field, a given mode being maintained over a range of magnetic field of the order of 8%. The anode voltage was about 70% of the critical value. The experimental results generally support the hypothesis and suggest that the minimum-voltage regime should be of extreme importance for work at the highest radio frequencies.

1558

621.396.615.142.2

Two-Cavity Klystron.—B. Meltzer. (*Wireless Engr*, Nov. 1949, Vol. 26, No. 314, pp. 365–369.) Two fundamental differential equations governing electron flow in the drift space are derived. They are valid only while the motion preserves its single-stream character, the limiting condition being when overtaking occurs. Thermal variations of velocity and forces due to the magnetic field of the current are neglected. The equations are integrated and applied to discussion of the plane diode, effects in the drift space of the klystron and in the klystron with space-charge-limited cathode.

MISCELLANEOUS

1559

539 + 658

1950 I.R.E. National Convention Program.—(*Proc. Inst. Radio Engrs*, Feb. 1950, Vol. 38, No. 2, pp. 192–211.) Summaries are given of the following papers:

1. Evolution and Growth of Industrial Designing.—J. Vassos.
2. Procedure in Industrial Designing.—C. Peterson.
3. Cost Reduction Possibilities in Industrial Design.—W. B. Donnelly.
4. Sales Attitude towards Industrial Design.—E. F. Toal.
5. News of the Nucleus.—U. Liddel.
20. Statistical Evaluation of Life Expectancy of Vacuum Tubes designed for Long-Life Operation.—E. M. McElwee.
21. Application of Statistics to Acceptance Specifications.—B. Koslow.
22. Statistical Methods in Research and Development.—L. Lutzker.
23. Statistical Engineering of Tolerances.—E. D. Goddess.
24. Top Management evaluates Quality in terms of Sound Engineering.—A. B. DuMont.
25. Statistics—A New Tool for the Planning and Analysis of Laboratory Experiments.—E. B. Ferrell.
163. Miniaturization Techniques: a Discussion and Proposal.—M. Abramson & S. Danko.

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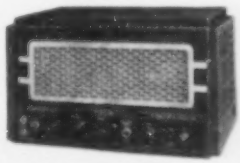

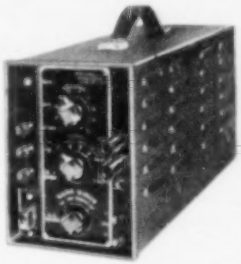

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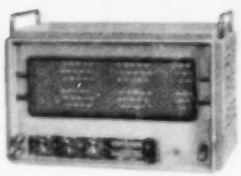

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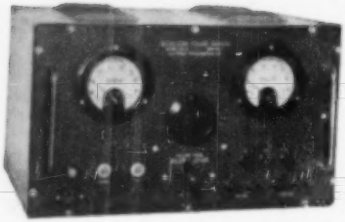

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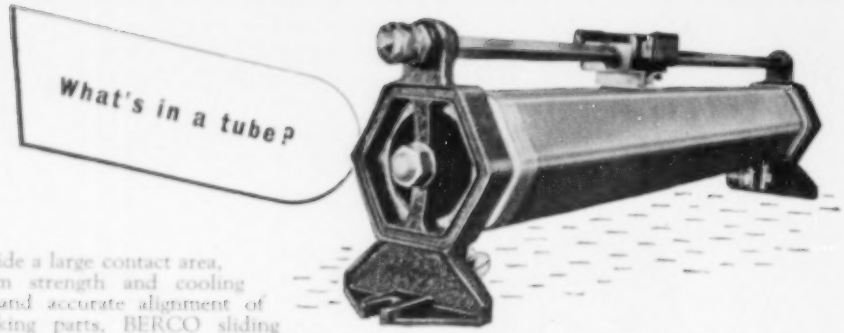

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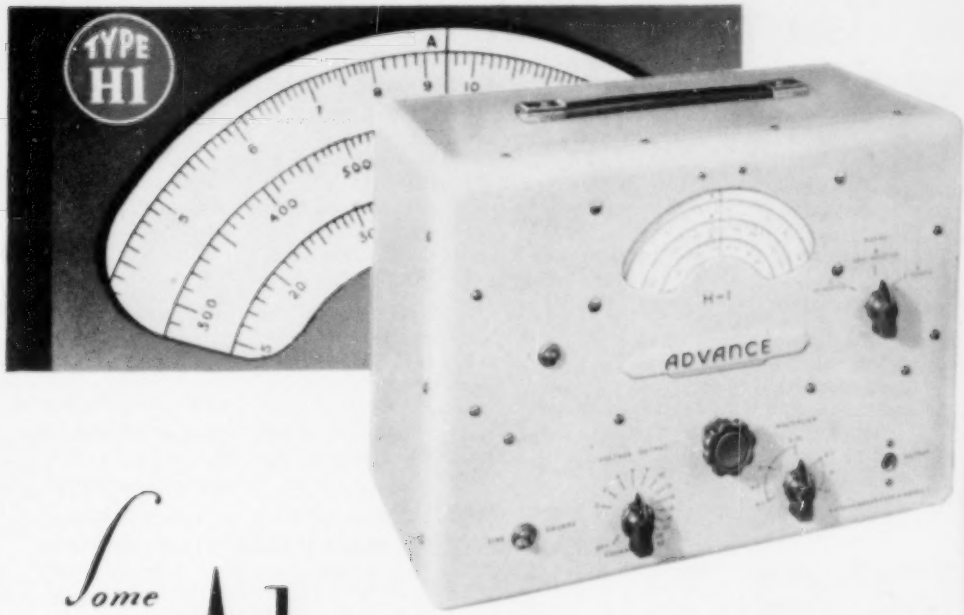

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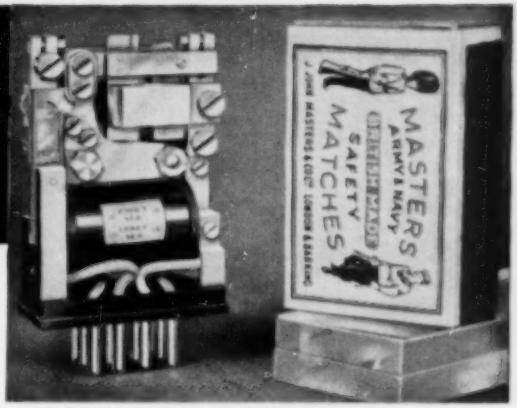

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Contact Pressure at 4 ampere turns R.M.S. 12 grammes. Maximum speed without bias disturbance or contact chatter, 60 c/s. At about 65 c/s. there is some bias, of the order of 5% but above this the Relay works faultlessly up to about 120 c/s.

TYPE 5C As Type 5A but with soldering tags instead of plug-in base.

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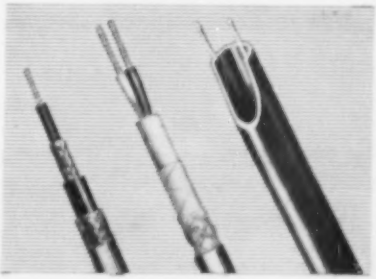

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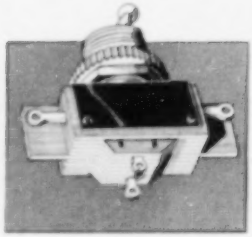

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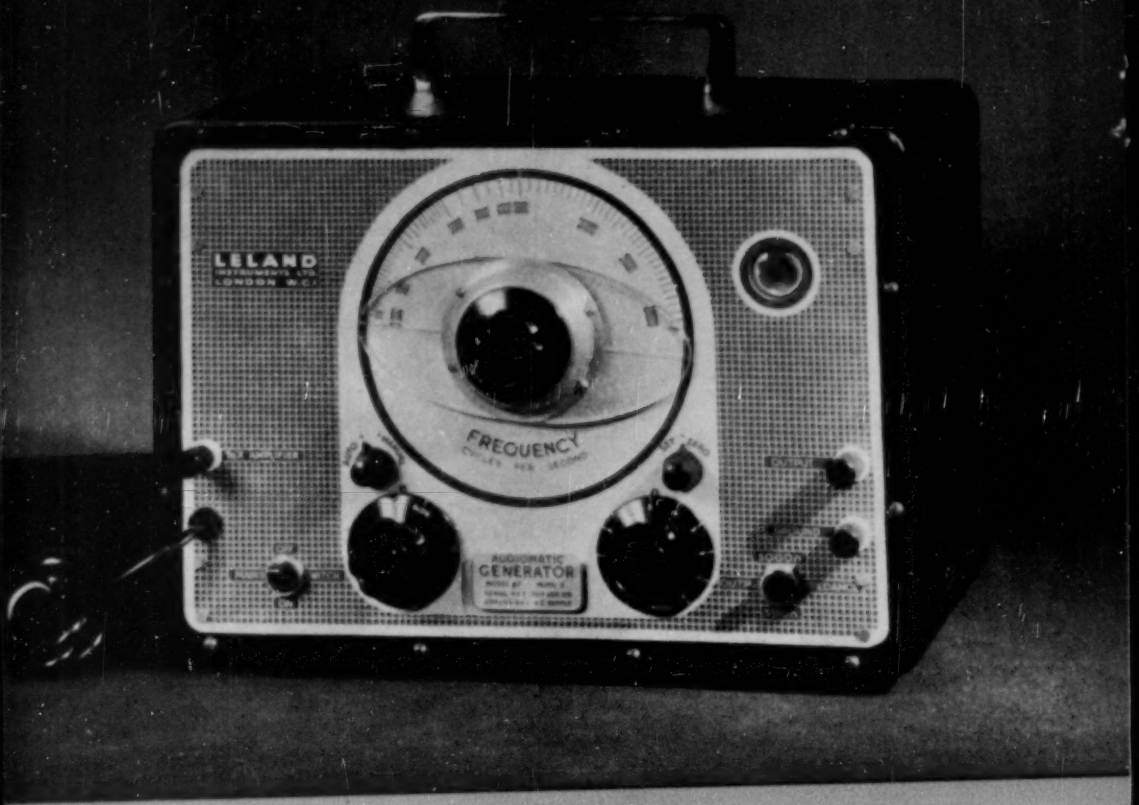

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